

XVIII. *Experiments in 1893, 1894, and 1896 upon the colour-relation between lepidopterous larvæ and their surroundings, and especially the effect of lichen-covered bark upon* *Odontopera bidentata*, *Gastropacha quercifolia*, etc. By EDWARD B. POULTON, D.Sc., M.A., LL.D. (Princeton), F.R.S., etc., Hope Professor of Zoology in the University of Oxford, Fellow of Jesus College, Oxford.

[Read June 3rd, 1903.]

PLATES XVI, XVII, AND XVIII.

THE circumstances under which the experiments recorded in the present memoir were undertaken, afford a good example of the stimulus and encouragement to work rendered possible by that mutual intercourse and exchange of experience and ideas which are promoted by meetings of scientific societies.

In the year 1892 I conducted an extensive series of experiments upon the adjustment of the colours of the larvæ of *Amphidasis betularia* to those of their environment (Trans. Ent. Soc. Lond., 1892, pp. 337-369). Living examples of the chief results obtained were shown at the meeting of Section D of the British Association at Edinburgh, on August 9th (Report of the 1892 Meeting, p. 786, where however the word "pupæ" is erroneously printed instead of "larvæ"). After the larvæ had been exhibited, Dr. Stacey Wilson, of Birmingham, asked if I had tried the effect of lichen-covered bark. Dr. Wilson stated that he had once beaten the larva from a food-plant with twigs covered by lichen, and that its appearance was entirely different from that usually borne by *betularia*. He looked upon it, in fact, as the larva of some other species, and was only convinced by breeding the moth (Trans. Ent. Soc. Lond., 1892, p. 360). The idea of making use of an environment of lichen-covered bark had not occurred to me, and I determined to try

the experiment on this and other suitable larvæ on the first opportunity.

I propose to state the results of these experiments forthwith, referring to the plates which accompany the paper. Hence it will be possible to gather the conclusions by looking at the few first pages, while those who desire to study the evidence in detail will find it recorded in the later part of the memoir.

The first larva which appeared suitable for the purpose was *Odontopera bidentata*, and Mr. G. T. Porritt very kindly consented to look out for eggs. Mr. Porritt had himself suggested to me that the larva would probably prove to be especially suitable for the purpose of this enquiry, and he wrote on May 9th, "the larva varies so very much in a wild state according to its food, that I fancy it will form an interesting subject for your experiments."* On May 9th, 1893, he kindly sent me from Huddersfield a batch laid by a single female, and, on June 13th, a second consignment laid by two females, from Sledmere on the Yorkshire Wolds. The first set afforded the material of Experiments I to IX (including VA) described in this paper. The second mixed set formed the subject of Experiments X to XVIII. The chief results of both experiments will be gathered by a glance at Plate XVI, in which figs. 1 to 5 represent larvæ from the first set of eggs, figs. 6 to 11 larvæ from the second set. At the same time results like those shown in the former figures were produced in larvæ of the second set and like those in the latter figures, in larvæ of the first set.

The detailed account of the experiments shows the number of days which elapsed before the influence of each environment became visible, and the time which was necessary in order to produce the full effect. A very large number of records proves that the larvæ, in the great majority of cases, rested by day upon the object which

* Dr. T. A. Chapman wrote to me (June 14, 1903), concerning the forms and habits of *bidentata*:—"About forty years ago, I took three or four beautifully green latticed larvæ off the lichen-covered trunk of an old alder-tree in Glen Messen (Argyleshire). They were quite new to me, and though very like (of course) *bidentata*, I thought they must be something else, a lichen-feeder. When they produced *bidentata*, I got no further than wondering whether *bidentata* was sometimes a lichen-feeder. I remember well their resting-place was near the ground, many feet from any leaves,—as long a journey for feeding as the larva of *Aprilina* makes."

they afterwards came to resemble. This, however, is probably not the case in the earliest stages, when the larvæ doubtless rest on the leaves and stalks.

The extreme sensitiveness of this larva is clearly shown by a glance at Plate XVI. The four first figures indicate a power of adjustment about equal to that of the most sensitive larva hitherto known, *Amphidasis betularia* (compare Trans. Ent. Soc. Lond., 1892, Plate XIV). The effect of green leaves and shoots, shown in fig. 5, is however very inferior to that produced upon *betularia*, which becomes bright green in this environment. The effect of green leaves alone upon *bidentata* is the same as that observed in many other larvæ, Noctuæ as well as Geometræ, viz. the reduction of the brown ground-colour to a very pale tint which would be far less conspicuous than the more ordinary appearance. The contrast between the results of an effective environment of green, and nothing but green, as shown in fig. 5, and of green scattered over a brown background of bark, as shown in figs. 6 to 11, is very striking, and suggests renewed experiments with an artificial arrangement of combined colours. Another interesting fact, suggesting the restriction of larval susceptibility to the *immediate* surface upon which the resting periods are passed, is the entire absence of any effects traceable to the green leaves of the food-plant when present with the other forms of environment employed in these experiments. The complex nature of the result produced is well seen in the oblique white lateral marks which are found in larvæ with the green lichen-like patches (figs. 6, 9), and probably assist in the general effect by breaking up the larval surface. The green markings are developed in the vicinity of and include the projecting ridges, etc.—a fact which is of obvious significance in promoting the resemblance to small scattered masses of lichen. The various kinds of lichen made use of did not produce corresponding effects.* Thus the green dorsal patches shown on the larvæ which had been exposed to orange lichen (figs. 8, 9) did not differ in any marked degree from those in which a green lichen had been chosen. It is by no means

* My friend Professor S. H. Vines, F.R.S., has very kindly given me the probable names of the lichens made use of. They will be found in the detailed account of the experiments, and in the description of Plates XVI to XVIII. The names could not be given with certainty because the specimens themselves had been lost.

unlikely, however, that under entirely normal conditions special detailed adjustments of this kind may be brought about. With regard to the sensitiveness to lichen, *bidentata* appears to be as superior to *betularia*, as it is inferior to the latter larva in sensitiveness to green leaves, so that the two species may be considered about equal in the power of colour adjustment. It is interesting to observe that dark purplish-brown twigs with white spots, although producing lighter larvæ than those upon unspotted but otherwise similar twigs (compare figs. 4 and 3), did not lead to the appearance of white marks upon the larvæ (fig. 4).

Dr. Stacey Wilson's experience led me to try the same experiments with an environment of lichen in the case of *A. betularia*. My friend Mr. Arthur Sidgwick kindly gave me a small batch of eggs in the summer of 1893, and the fourteen young larvæ which hatched from them were subjected, together with *bidentata*, to this form of environment, in Experiments XII to XV. It will be seen however that eleven of the resulting larvæ were yellowish-green, two brownish-green, and one grey mottled with brown.

The same experiments produced the larvæ of *bidentata* of which typical examples are represented in Plate XVI, figs. 6—11. So far as any conclusion can be drawn from these four small experiments, *betularia* does not seem to be nearly so sensitive or so specialized to this form of environment as *bidentata*. At the same time lichen must have been the cause of the *betularia* larvæ, with one exception, becoming green; for ordinary bark tends strongly to the production of dark forms of this species, even in the presence of a great preponderance of green leaves (Trans. Ent. Soc. Lond., 1892, pp. 331, 332). It will be of interest to repeat these experiments upon a much larger scale, and to introduce the larvæ immediately after hatching; but it does not appear to be probable that this species often exhibits the kind of susceptibility to lichen observed by Dr. Wilson; for (1) it is remarkably sensitive to other surroundings almost throughout its life-history (see pp. 318—320), and (2) the four small experiments, conducted in 1893, do prove considerable sensitiveness to lichen although they did not lead to the production of lichen-like larvæ.

The fortunate discovery of a company of young larvæ

of *Gastropacha quercifolia* by Mr. W. Holland, on July 22nd, 1893, enabled me to experiment on this interesting species, which is well known to present grey and lichen-like forms. The company, evidently the product of a single batch of eggs, was so numerous that I was able to start four experiments with fifteen larvæ in each, on July 28th. All were fed on hawthorn, the food-plant on which the larvæ had been found. This in three cases was intermixed with environments more or less harmonizing with known varieties of the larva—the rough black-barked twigs of the Turkish oak, bramble-stems of a rich reddish-brown colour, and sticks bearing an abundant growth of lichen (probably *Ramalina farinacea* in all cases). In the fourth case the larvæ were as far as possible restricted to the green leaves and youngest shoots of their food-plant. It was, however, impossible altogether to exclude shoots of greyish and reddish-brown shades, and these probably produced some effect.

At first the young larvæ rested chiefly on the food-plant, but soon preferred the bark of the older wood. The change took place simultaneously in each of the three sets containing dark bark and lichen, as will be seen by a glance at the following summary of Mr. Holland's careful notes:—

Dates.	I.		II.		III.	
	Food-plant.	Black bark	Food-plant.	Lichen-covered bark.	Food-plant.	Reddish-brown bark.
Aug. 1.	12	3	14	1	14	1
Aug. 5.	4	11	3	12	5	7 *
Aug. 9.	3	12	1	14	1	13 †

* 3 on muslin roof. † 1 missing.

There is no reason to suppose that these effects were due to any gradual recovery from disturbance. The recently hatched larvæ were found at the tip of a young shoot on July 22nd, and it is probable that by August 5th the period had been reached when they begin to seek the older wood for the diurnal rest. After August 9th only single larvæ were found except upon the environments which had been provided, and it is probable that, under

entirely natural conditions, larvæ of the same age would never be found upon the leaves or green shoots.

It is of interest to note that the larvæ never rested upon the lichen itself, but upon the bark of the sticks between the masses of lichen. This position is consistent with the larval appearance, which is that of bark partially grown over with lichen.

There can be little doubt that the larva is influenced by the colours of the environment from the time at which it first seeks the older wood, but a certain period is required before the effects become visible. A very obvious adjustment to the three forms of environment was recorded on August 14th—so obvious indeed that the first trace of a visible result might probably have been detected some few days earlier. The adjustment continued to become more complete right up to the beginning of hybernation. On Aug. 31st it was noted that the effects of the three environments had greatly increased. On Sept. 21st a careful comparison of all the larvæ was made upon a white paper background. It was then thought that the adjustment was as complete as it was likely to be before hybernation, and for many larvæ this conclusion was justified. In others however the effects continued to deepen right on into October, as will be seen in the complete account of the experiments. The latest changes probably took place after the larvæ had ceased to feed; indeed they had eaten very little for some time previous to October 3rd. The degree of cryptic adjustment to the three environments which had been reached by the beginning of hybernation can be seen by a glance at the upper part of Plate XVII, where examples of all the types of colouring are represented.

In arranging the larvæ for hybernation many of the environments were shifted, in order to test the existence of any larval susceptibility during this period; and, as no effects were visible when the larvæ were compared after the winter, these same surroundings were continued in each case, right up to the time when the nearly mature larvæ were sent to Lord Walsingham for preservation, in May. The results of various comparisons point to the conclusion that the larvæ of *G. quercifolia* are not susceptible to the colours of the environment after the beginning of hybernation. Thus Plate XVIII, fig. 1 represents a nearly mature larva, of which the appearance before

hybernation is shown in either fig. 4 or fig. 9 on Plate XVII. The latter appearance was a response to an environment of lichen-covered sticks; but after October 16th these were replaced by black-barked twigs, which it is seen produced no effect at all. Again, Plate XVIII, fig. 2 represents a later stage of Plate XVII, fig. 6. Here too the resemblance between older and younger larvæ is very close, although the former had been subjected to the same black environment after October 16th. The negative result of a transfer experiment in the opposite direction is seen in Plate XVII, fig. 14, the representation of a larva which had been exposed to lichen-covered sticks after October 3rd. All the larvæ did not remain as uniform throughout their life-history as these three. Thus Plate XVIII, fig. 3 represents a nearly mature larva of which the appearance before hybernation is seen in Plate XVII, figs. 4 or 9. In this case the larva darkened considerably after the winter, although its environment had not been shifted, but consisted of lichen-covered sticks throughout.

It is probable that the power of adjustment to environment possessed in so marked a degree by this species is specially directed to protection during hybernation, when the food-plants are leafless, and when enemies are often pressed by hunger. But it is doubtless also of importance later on when the larva becomes so much larger and would on this account be far more conspicuous. It is probable, however, that the caterpillar does not wander from its food-plant, and that complete adjustment to the old wood before hybernation is an adequate defence in the following spring and summer. If this be correct there would be no advantage in a prolonged larval susceptibility.


















The same relationship between susceptibility and the particular needs of each species is seen in the effect of an environment of green leaves and shoots upon *G. quercifolia*, *O. bilentata*, and *A. betularia*. The first-named probably invariably rests by day, except for a brief period after leaving the egg, upon the older wood, and the power of adjustment to leaves and young shoots, being altogether useless to it, has never been acquired. The last-named, with its remarkable range of food-plants, including many, such as broom or rose, in which green shoots are a prominent feature, is frequently in a position in which a green colour would best conceal its nearly smooth and cylindrical form; and we find that, as a matter of fact,

it always responds in this way to an environment of the kind described above. *Bidentata* doubtless occupies an intermediate position between the other two species in this respect. The occasions are probably rare, but not altogether wanting, in which it is compelled to develop in a green environment. We find that it has the power of making some considerable approach towards such surroundings, but not of attaining any high degree of resemblance to them. It is probably the case, however, that the tint which it produces on green leaves and shoots is of great value on a pale yellowish-brown bark, which may often form its environment; and it may well be that it is something in common between the light reflected from this and from green leaves which explains the similarity in the effects produced upon the larvæ.

Typical examples of all the forms of *quercifolia* larvæ produced in these experiments were shown alive at the meeting of the Entomological Society of London on May 2nd, 1894, and also at the Soirée of the Royal Society in the same month. A brief account of the exhibit is printed in the Proc. Ent. Soc. Lond., 1894, p. xvi. It is also referred to in Mr. C. G. Barrett's "Lepidoptera of the British Islands" (Lond., 1896, vol. iii, p. 45).

The nearly mature larvæ of *quercifolia*, forming the subject of the experiments described in this memoir, were in almost every case sent to Lord Walsingham, and, with the exception of one which was spoilt, were kindly preserved by him. The specimens are now to be seen in the Hope Department, Oxford University Museum, and in the British Museum of Natural History.

The last series of experiments described in this paper grew out of the surprising restriction of susceptibility to the younger stages of *G. quercifolia*. The results naturally suggested further experiments upon other species well known to be highly sensitive, and I immediately fixed upon *Amphidusis betularia* as the most suitable for the purpose. The investigation was carried out entirely by the present writer, in the laboratory at Wykeham House, Oxford. The results are clearly shown in the accompanying diagram and summary. The Roman figures represent the corresponding stages of larval life. The shaded squares indicate stages passed in a black environment, the unshaded, stages passed in the green surroundings.

Experiment.	I.	II.	III.	IV.	V.	VI.	Colour of mature larvæ.
B							5 green, 1 intermediate.
B ³							1 dark smoky-black. 1 greenish-brown (intermediate). 1 greyish smoky-black.
B ²							9 black (1 dark brownish, 3 with dull greyish patches). 1 grey.
B ¹							4 black.
C ¹							5 black (overspread with grey). 1 brownish-black.
C							6 dark (with grey patches). 3 intermediate.
A							3 dark (respectively overspread with grey, greenish on sides, and with pale yellowish spots). 1 green (with brown dorsal line and lateral patches).
A ²							2 black. 2 dark overspread with grey. 1 bright green.
A ¹							2 green, sprinkled with grey, 1 greenish intermediate. 1 whitish, 2 blackish with grey markings. 1 distinct but dull green with brown broad dorsal line and slight lateral traces.

A glance at the diagram and results proves conclusively that there is no restriction of susceptibility to the younger stages of this species. Experiment B³ shows the strong influence of a black environment applied only to the two latest stages, while A¹ shows considerable effects traceable to black which was present in the 2nd stage only. When

we furthermore take into account the more intense effects which were produced as additional stages were exposed to a dark environment, we may feel confident that every stage except the 1st and the 5th or 6th, is sensitive. These require further experimental testing.

A very interesting and unlooked-for effect was produced in many of the transferred larvæ, viz. an overspreading greyness or the appearance of grey patches. Thus, although the effect of the earlier surroundings appeared at first sight to be entirely obliterated, the larvæ were nevertheless unable to develop their full and characteristic response to the later environment. Details will be found in the account of the experiments. It only remains to point out that experiment A¹ probably indicates that these larvæ are susceptible to the colours of the branches at a period when they are at any rate chiefly to be found upon the leaves and leaf-stalks, and that there was some evidence to show that the influence of environment may be largely a question of time, so that of several larvæ passing the same stages in given surroundings, those which grow most slowly are, on the whole, the most affected.

FIRST EXPERIMENTS WITH LARVÆ OF *O. BIDENTATA* (1893).

The larvæ from the first set of eggs sent by Mr. Porritt from Yorkshire hatched at about the same time, so that nearly all the experiments recorded on pages 322—325 in a tabular form were started on the same day, May 22nd. The observations were in part conducted by Mr. Holland and in part by me, as is indicated by the initials or name under the dates in the left-hand column of the table. Hence in the account of each experiment there is the opportunity of comparing two independent sets of observations.

The food-plant made use of in all these experiments was the black poplar (*Populus nigra*).

A careful comparison of the results of the 10 sets of experiments (viz. I to IX, including VA) was made by the present writer on July 6th, 1893, all the larvæ being placed on a background of white. At this time all except one were in the last stages, and many in all the cylinders were approaching maturity. Of the forms of environment made use of, 7 had produced dark larvæ, and 3 light.

A. DARK LARVÆ OF BIDENTATA ON JULY 6TH.

I. *Black sticks*.—Fourteen out of the 15 larvæ were very black, the exception being quite small and probably in the 3rd stage. These larvæ were the darkest of all the sets.

II. *Deep blue paper spills*.—These 12 larvæ were very dark, coming next to those upon the black twigs in this respect. The dark purplish-black colour was also very uniform over the whole larval surface corresponding to the unvarying tints of the environment.

III. *Purplish-brown twigs*.—These 15 larvæ were *slightly* more variegated than II, in correspondence with the less uniform darkness of their environment. Except for this slight introduction of rather lighter shades these larvæ were as dark as II.

IV. *White spotted purplish-brown twigs*.—These 16 larvæ were dark, but distinctly lighter than those of the three previous sets. They also varied a little, whereas the groups first described were more uniform. Although the relative lightness and the darkness of these larvæ, as compared with III, corresponded to the *general* effect of their respective environments, there was no marked resemblance to the special details of the twigs which had been carefully selected for Experiment IV.

V. *Brown twigs*.—The 17 larvæ were distinctly brown and not nearly so black or purplish as the preceding sets. The shade of brown varied, being much lighter in the smaller larvæ. The brown larval surface was also somewhat variegated with different shades of the same colour.

VA. *Bark overspread with a bright yellowish-green powdery lichen*.—The 18 larvæ varied very greatly, some being as dark as the blackest of set I; many were variegated with shades of brown, harmonizing well with the environment; for the lichen soon lost its green tint and became various shades of brown. This is the only note relating to this experiment which has been found. There is no doubt that the young larvæ were introduced on May 22nd or 23rd.

VI. *Lichen-covered sticks*.—The lichen was probably dead and had become much paler. These larvæ too were much lighter than any of the previous sets, although a few were quite dark. Nearly all were light brown and much variegated with shades of brown, harmonizing well with the environment.

Of the 7 sets of larvæ described above, the degrees of

Dates in 1893.	I. Black twigs of Turkish oak.	II. Deep blue paper spills.	III. Dark purplish-brown glossy twigs probably of birch.	IV. White-spotted purplish-brown twigs of birch.
May 22. (E. B. P.)	15 Young larvæ introduced.	(May 23.) 15 young larvæ in- troduced.	15 larvæ in- troduced (just hatched).	16 young larvæ introduced.
June 11. (E. B. P.)	(June 9.) Re-fed.	12 larvæ counted; becoming very dark.	(June 16). All 15 dark like the twigs, but not markedly purplish.	15 counted.
June 19. (E. B. P.)	(June 17.) All 15 very black like the twigs.	All 12 very dark.	All 15 on twigs, very dark and purplish.	12 larvæ on twigs, 4 on green. All dark, but greyer than those in III, and not so dark as latter.
June 25. (E. B. P.)	(June 22.) As before. All at rest on twigs.	As before. All on spills.		
July 1. (E. B. P.)	As before: all on twigs.		(June 27.) All 15 dark brown.	(June 27.) Re-fed.
July 6. Careful com- parison on white paper. (E. B. P.)	2 at rest on green, 13 on twigs. All very black.	9 on spills, 1 on green, 2 not noted. All 12 of a uniform dark purplish- black.	All 15 on twigs. All very dark.	13 on twigs, 3 on green. Dark, but much lighter and less constant than III.
July 10. (W. Holland.)	2 at rest on green, 13 on twigs. All very black.	8 on spills, 4 on green. All very dark.	14 on twigs, 1 on green. All dark purplish-brown.	15 on twigs, 1 on green. The larvæ remain lighter in tint than III.
July 12. (W. Holland.)	15 on twigs.	9 on spills, 3 on green.	13 on twigs, 2 on green.	13 on twigs, 3 on leaves.

V. Reddish-brown twigs.	VI. Lichen-covered sticks.	VII. Weathered pale grey barkless twigs.	VIII. Green leaves and shoots of food-plant (<i>Populus nigra</i>).	IX. Orange paper spills.
17 young larvæ introduced.	14 young larvæ introduced.	(June 3.) 15 young larvæ in- troduced.	15 young larvæ introduced.	15 young larvæ introduced.
All 17 evidently becoming brown like the twigs.	(June 9.) Re-fed.	Apparently be- coming light brownish and ap- proaching colour of twigs.	All 15 very pale brown	
Brown like the twigs.	14 larvæ; vari- able, with no marked resem- blance to lichen.	(June 18.) 13 on twigs, 1 on muslin roof, 1 on green. All closely resemble twigs.	(June 17.) All 15 very pale brown, some faintly greenish.	6 on spills, 1 on muslin roof, 8 on green. All very light brown.
As before. 14 on twigs, 2 on green, 1 uncertain.	10 on sticks, 4 on green. Some distinctly varie- gated light and dark brown, but no green marks yet.	(June 22.) 10 on twigs, 1 on muslin, 3 on green.	(June 22.) As before.	14 on spills, 1 on green. Colour as before.
All 17 on twigs. They become much lighter when changing skin.	9 on sticks, 5 on green. Larvæ still very varie- gated.	13 on twigs, 1 on green.		
17 on twigs. Distinctly brown, and not purplish like III and IV.	12 on sticks, 2 on green. A few dark but mostly light and varie- gated with shades of brown.	All 14 light grey and harmonizing perfectly with twigs.	14 larvæ. All very light brown, but not greenish.	All 15 on spills. Larvæ resemble VIII, only not <i>quite</i> so light.
16 on twigs, 1 on green. All brown as before.	12 on sticks, 2 on green. Two larvæ variegated with dark green: the rest as before, but darker brown.	10 on twigs, 4 on green. 1 larva injured. Appear- ance as before.		11 on spills, 4 on green. Very light yellowish- brown.
16 on twigs, 1 on green.	13 on sticks, 1 on green. 4 larvæ with dark green patches, strongly developed in 2 of them.	11 on twigs, 2 on green.		12 on spills, 3 on green.

Dates in 1893.	I. Black twigs of Turkish oak.	II. Deep blue paper spills.	III. Dark purplish-brown glossy twigs probably of birch.	IV. White-spotted purplish-brown twigs of birch.
July 15. (W. Holland.)	15 on twigs. All very black.	10 on spills, 2 on green. All very dark.	14 on twigs, 1 on green. All very dark purplish- brown.	12 on twigs, 4 on green. Colour darkish brown but distinctly paler than III.
July 18. (W. Holland.)	As before.	As before.	As before.	As before.
July 23. (W. Holland.)	As before.	Some mature and spinning up.	As before.	As before.
July 27. Careful com- parison (E. B. P.)	Some pupating. All black, but one has <i>very</i> faint traces of green on sides anteriorly. These larvæ black and less purple than those with blue spills (II).	6 larvæ remain, nearly mature. All <i>very</i> dark purplish, almost black, as on many previous occasions.	All a very uniform dark purplish- brown, almost black, but not so much so as those with the blue spills.	All dark greyish- brown and very uniform.
July 28. (W. Holland.)	8 larvæ still feeding. All on twigs.	5 still feeding. 4 on spills, 1 on leaf.	9 still feeding: all on twigs. (July 30.) A typical larva painted; shown in Plate XVI, fig. 3.	12 still feeding: all on twigs. (July 30.) A typical larva painted; shown in Plate XVI, fig. 4.
Aug. 3. (W. Holland.)	(July 31.) A typical larva painted; shown in Plate XVI, fig. 1. (Aug. 4.) Re-fed.		5 still feeding. 4 on twigs, 1 on green.	6 feeding. All on twigs.
(Aug. 8. W. Holland.)	Re-fed. One or two still feeding.		As before. All 5 on twigs.	5 feeding: all on twigs. Colour as before. (Aug. 19.) 3 still feed- ing.

V. Reddish-brown twigs.	VI. Lichen-covered sticks.	VII. Weathered pale grey barkless twigs.	VIII. Green leaves and shoots of food-plant (<i>Populus nigra</i>).	IX. Orange paper spills.
10 on twigs, 7 on green. All brown like twigs.	10 on sticks, 4 on green. 6 with green patches, very marked in 2.	12 on twigs, 1 on green. All very pale and extremely like twigs.		11 on spills, 4 on green. All pale yellowish- brown.
As before.	As before. Some larvæ mature.	As before.		As before.
Some larvæ mature.	Others mature.	As before.		Some larvæ mature.
Some larvæ have become of a much darker brown lately. The change probably due to maturity.	3 or 4 with green patches, 3 or 4 with brown.	All now much darker, but still like the darker twigs in the cylinder. Some mature.	Larvæ very light brown, like IX.	Very light brown, like VIII.
10 still feeding. 8 on twigs, 2 on green.	7 feeding. All on sticks.	10 feeding; all on twigs. A typical larva was painted; shown on Plate XVI, fig. 2.	(July 31.) A typical larva painted; shown on Plate XVI, fig. 5.	7 feeding, all on spills.
4 feeding. All on twigs.	2 feeding.	6 on twigs, 1 on green.	6 feeding. All pale brown.	5 feeding. 4 on spills, 1 on muslin.
(Aug. 19.) 1 still feeding.	(Aug. 18.) All pupated.	7 still feeding. (Aug. 19.) 2 still feeding.	5 feeding, 1 dead. (Aug. 19.) 5 feeding; all very pale brown. 4 feeding on Aug. 26, and 1 or more on Aug. 31.	As before. All 5 on spills. (Aug. 20.) All pupated.

darkness follow in the same order as that in which the results are recorded, except that V and VA were much alike, the brown differing in tint rather than in depth. VI were much lighter than any of the others.

B. LIGHT LARVÆ OF BIDENTATA ON JULY 6TH.

VII. *Weathered grey barkless twigs*.—The larvæ were very light; of a distinct grey colour, harmonizing perfectly with the environment.

VIII. *Green leaves and shoots of food-plant*.—The 14 larvæ were all *very* light brown but not at all greenish.

IX. *Orange paper spills*.—The 15 larvæ closely resembled VIII, but were not quite so light.

Some of the results of this comparison have been incorporated in the tabular statement. Another careful comparison was made on July 27th, but in this case it was possible to include the whole in the table.

SECOND EXPERIMENTS WITH LARVÆ OF *O. BIDENTATA*.

EXPERIMENTS WITH LICHEN ON LARVÆ OF *A. BETULARIA* (1893).

In sending the second mixed set of eggs of *bidentata*, Mr. Porritt wrote on June 13th, 1893—"I certainly had no expectation of seeing any more *Odontopera bidentata* this season. However, when collecting on Saturday, at Sledmere, in a high wood on the Yorkshire Wolds, I found several! Two of the females have deposited a few eggs, which I forward at once with this. Sledmere is on the chalk, and *bidentata* there is quite of a different type to our West Riding moth, being of the pale, ochreous banded, distinctly southern form."

The eggs were placed in a single cylinder, and as soon as a sufficient number of larvæ had hatched, I started Experiments X to XV, between June 27th and July 3rd, the 14 larvæ of *A. betularia* received from Mr. Arthur Sidgwick being divided between Experiments XII to XV. Experiments XVI to XVIII were started on August 3rd by Mr. Holland, with the latest larvæ of *bidentata*. All the observations on Experiments X to XVIII recorded in the tabular statement on pages 328—331 were made by Mr. Holland. The food-plant used throughout was *Populus nigra*. When flat pieces of bark were introduced (XII,

XIII, XIV, as well as VA in the first series of experiments), they were tied together in pairs with the lichen-covered surfaces outwards.

EXPERIMENTS XVI, XVII, AND XVIII WITH THE LARVÆ
OF *O. BIDENTATA* UPON GREEN LEAVES AND SHOOTS
OF THE FOOD-PLANT (*Populus nigra*).

The results of these experiments were uniform, and require so little description that a tabular form of presentation is unnecessary.

Experiments XVI (10 young larvæ), XVII (17 larvæ), and XVIII (14 larvæ) were begun by Mr. Holland on August 3rd, 1893. He recorded that the larvæ of XVI were pale brown, 2 of them rather variegated; while of XVII, 14 were pale brown and 3 rather variegated. Of XVIII no record was made. The larvæ were the last hatched from the mixed batch of eggs which supplied the material for Experiments X to XV.

August 8th. All re-fed. Sixteen larvæ in XVII.

August 12th. XVI and XVIII re-fed; the latter noted as nearly all pale brown, a few rather variegated.

August 15th and 19th. XVI and XVIII re-fed; larvæ 10 and 14 respectively.

August 17th. XVII re-fed; 16 larvæ.

August 21st. XVII re-fed; 8 larvæ had escaped. The 10 larvæ in XVI were all of a pale brown colour.

August 22nd. XVIII, 13 larvæ pale brown, 1 darker with a few green markings.

August 26th and 31st. All re-fed; larvæ 10, 8, and 14 respectively.

September 5th. XVI, becoming mature (2 still feeding on 9th and 13th; no further notes on this set). XVII, 7 larvæ, all pale brown. XVIII, 14 larvæ.

September 8th. XVII, 2 mature (all mature on 13th). XVIII, 1 mature, 1 dead. Of 12 still feeding, 10 pale brown, 2 rather darker brown. Two out of the 12 slightly tinged with green.

September 13th. XVIII, 6 still feeding. On the 18th they were neither pupating nor feeding, and on the 23rd the last died. It appears possible that there was a tendency towards hibernation on the part of the larvæ with the slowest rate of growth.

Dates in 1893.	X. Dark purplish-brown glossy twigs, probably of birch.	XI. Reddish-brown twigs.	XII. Bark covered with bright yellowish-green powdery lichen, the colour of which faded and left the dark bark.
June 27.	(July 2.) 13 small larvæ introduced, mostly in 2nd stage.	(July 3.) 20 larvæ introduced, at beginning of second stage. The smallest about 5.5 mm. long, and none much longer.	3 <i>betularia</i> , smaller than in XIII and XV, introduced. 15 <i>bidentata</i> , similar to those introduced in XIII.
July 12.	Half of the larvæ becoming purplish.	20 counted. A few becoming reddish-brown.	3 <i>betularia</i> , pale yellowish-green. 15 <i>bidentata</i> variegated.
July 15.	Re-fed.	Re-fed. 20 counted.	Re-fed. 3 and 15 counted.
July 18.	9 on twigs, 4 on green.	10 on twigs, 8 on green. Larvæ becoming dark reddish-brown and variegated.	2 <i>betularia</i> , mature. 14 <i>bidentata</i> , all darkish, variegated.
July 23.	(July 24.) 12 on twigs, 1 on green. Almost all dark.	15 on twigs, 1 on green, 1 on muslin. As before.	Last <i>betularia</i> mature. 10 <i>bidentata</i> on bark, 1 on green, 3 on muslin. All variegated brown, slightly touched with green and with white dashes along sides.
July 28.	12 on twigs, 1 on green. 10 dark brown, variegated; 3 paler and less variegated.	(July 27.) 12 on twigs, 4 on green, 1 on muslin. 8 changed skin and of a more uniform brown colour.	13, all on bark (as also on Aug. 1). About half darker, but all still variegated. All except 2 with more or less green.
Aug. 3.	11 on twigs, 2 on green. 11 dark brown and more uniform than before, 2 rather paler. One or two have patches of pale green.	(July 31.) 14 on twigs, 1 on green. 8 brown like the twigs; 4 paler and less uniform; 3 variegated and patched with green. (Aug. 4.) 12 on twigs, 2 on green, 1 on muslin. As before.	12 on bark, 1 on muslin. As before, but have become darker. This is the darkest set of Experiments XII to XV.

<p>XIII. Bark covered with bluish-green lichen, probably <i>Physcia pulverulenta</i>.</p>	<p>XIV. Bark covered with orange lichen, probably <i>Physcia parvictina</i>, combined with <i>P. pulverulenta</i>.</p>	<p>XV. Lichen-covered sticks. The lichen probably <i>Romaliina farinacea</i>.</p>
<p>3 <i>betularia</i>, about 12 mm. long, introduced. 12 <i>bidentata</i>, about 6 mm. long, introduced, mostly changing skin.</p>	<p>(June 25.) 4 <i>betularia</i>, about 7 mm. long, introduced. 1 changing first or second skin, others rather larger. 8 <i>bidentata</i>, about 6 mm. long, introduced.</p>	<p>4 <i>betularia</i> and 10 <i>bidentata</i> introduced. Both similar to those in XIII.</p>
<p>2 <i>betularia</i> yellowish-green, 1 brownish-green. 10 <i>bidentata</i> much variegated.</p>	<p>3 <i>betularia</i> pale yellowish-green, 1 grey mottled with brown. 2 much smaller than others. <i>Bidentata</i> rather pale, variegated.</p>	<p>3 <i>betularia</i> yellowish-green, 1 dark brownish-green. <i>Bidentata</i> mottled.</p>
<p>Re-fed. 3 and 10 counted.</p>	<p>2 yellowish - green <i>betularia</i> still feeding.</p>	<p>4 and 10 counted, <i>Betularia</i> as before.</p>
<p><i>Betularia</i>, all mature. 9 <i>bidentata</i> much variegated.</p>	<p>All <i>betularia</i> mature. 4 <i>bidentata</i> on bark, 3 on green. All brightly variegated.</p>	<p>3 <i>betularia</i> mature, 1 escaped. 10 <i>bidentata</i> dark, mottled; some green on sides.</p>
<p>8 on bark, 1 on green. 2 seemed unhealthy. All much variegated with pale brown and green. Small white dashes on sides.</p>	<p>4 on bark, 3 on green. All brightly variegated with shades of brown, and patched with green.</p>	<p>(July 24.) 8 on sticks, 1 on green, 1 on muslin. Nearly all patched with green.</p>
<p>7 on bark, 1 on green. Colours as before. Typical larvæ painted, Aug. 1st and 3rd, shown in Plate XVI, figs. 6 and 7.</p>	<p>6 on bark, 1 on green. As before.</p>	<p>10 on sticks. 6 darkish brown mottled with green and paler brown; white dashes on sides. 3 similar but paler. 1 without green.</p>
<p>8 on bark. 1 unhealthy. 6 brown, lighter than in XII, brightly mottled with paler brown and green. 1 paler, less variegated, with little green. 1 small and pale, without green. White lateral dashes only on former 6.</p>	<p>7 on bark. All changed skin. 1 blackish-brown, 4 darkish brown, 2 lighter brown; all variegated with much green, and the darker ones also with paler brown. All with lateral white dashes.</p>	<p>7 brown, more or less patched with green, some very strongly. 1 grey and brown strongly patched with pale green. 2 pale brown with little green. Most show white lateral dashes.</p>

Dates in 1893.	X. Dark purplish-brown glossy twigs, probably of birch.	XI. Reddish-brown twigs.	XII. Bark covered with bright yellowish-green powdery lichen, the colour of which faded and left the dark bark.
Aug. 8.	9 on twigs, 4 on green. All dark brown, some with a little green.	(Aug. 7.) 14 on twigs, 1 on green.	10 on bark, 3 on green. 10 of a rich dark brown patched with lighter brown and green: 3 lighter brown variegated with still paler brown and green. All but one of these paler larvæ with little white dashes on sides. The green marks less pronounced than in XIII and XIV.
Aug. 12.	(Aug. 10.) 11 on twigs, 2 on green. 11 purplish-brown, 2 rather paler. Several larvæ with green patches on sides.	(Aug. 10.) 13 on twigs, 2 on green. All brown, mostly rather darker than twigs, but 4 rather paler. Several patched with green.	10 on bark, 2 on green, 1 on muslin.
Aug. 15.	12 on twigs, 1 on green. As before.	12 on twigs, 3 on green. As before.	(Aug. 14.) 10 on bark, 2 on green. All but 2 very dark brown, with far less green than XIII and XIV.
Aug. 19.	10 on twigs, 2 on green. Purplish-brown, several with a little green. 2 rather paler brown.	10 on twigs, 5 on green. All brown, several patched with green.	12 larvæ, as before.
Aug. 21.	8 on twigs, 4 on green. 10 purplish-brown, 2 brown. Only 1 or 2 slightly marked with green.	(Aug. 22.) 12 on twigs, 3 on green. All brown, 8 resembling twigs, 2 rather darker, 2 rather lighter.	(Aug. 22.) 9 on bark, 3 on green.
Aug. 26.	(Aug. 25.) 12 on sticks.	Re-fed.	10 on bark, 2 dead.
Aug. 30.	9 on sticks, 2 on green. 1 mature.	2 mature, and 2 more on Aug. 31.	6 on bark, 4 on green. The colour of the lichen had faded, and left the dark bark.
Sept. 5.	Mostly mature. 2 feeding Sept. 8. All mature Sept. 13.	(Sept. 4.) Nearly all mature. Only 1 feeding Sept. 9.	(Sept. 4.) Larvæ becoming mature. A few still feeding Sept. 9 and 13.

<p>XIII. Bark covered with bluish-green lichen, probably <i>Physcia pulverulenta</i>.</p>	<p>XIV. Bark covered with orange lichen, probably <i>Physcia parietina</i>, combined with <i>P. pulverulenta</i>.</p>	<p>XV. Lichen-covered sticks. The lichen probably <i>Ramalina farinacea</i>.</p>
<p>5 on bark, 2 on green. As before.</p>	<p>7 on bark. As before. Typical larvæ painted Aug. 4 and 5, shown in Plate XVI, figs. 8 and 9.</p>	<p>10 on sticks. As before.</p>
<p>(Aug. 14.) 7 on bark. As before, except that smallest larva now marked with green.</p>		<p>(Aug. 10.) A typical larva painted, shown in Plate XVI, fig. 10.</p>
	<p>(Aug. 14.) 7 on bark. Lighter and greyer ground-colour. Green patches very marked.</p>	<p>(Aug. 14.) 10 on sticks. 8 grey-brown mottled with darker brown and much green, so that some are half green; 2 similar but browner.</p>
<p>7 on bark. Brown, variegated with paler brown and with green (strongly 5, less strongly 2).</p>	<p>5 on bark, 2 on green. Colour as before.</p>	<p>10 on sticks. Colour as before.</p>
<p>6 on bark, 1 on green. Colour as before.</p>	<p>6 on bark. All varie- gated greyish-brown, strongly patched with green. White lateral dashes.</p>	<p>10 on sticks. As before.</p>
<p>(Aug. 25.) 6 on bark, 1 on green.</p>	<p>(Aug. 25.) 6 on bark.</p>	<p>(Aug. 25.) 9 on twigs, 1 on floor.</p>
<p>2 mature. A typical larva painted Aug. 31, shown in Plate XVI, fig. 11.</p>	<p>6 on bark. Colour as on Aug. 21.</p>	<p>Larvæ becoming mature.</p>
<p>(Sept. 4.) All mature.</p>	<p>All mature except one. Last mature Sept. 8.</p>	<p>All mature.</p>

EXPERIMENTS UPON THE LARVÆ OF GASTROPACHA
QUERCIFOLIA (1893-4).

On July 22nd, 1893, Mr. W. Holland found a company of young larvæ of this species crowded together towards the end of a shoot of hawthorn near Steeple Aston, Oxfordshire. They were all the same size, and had evidently not long before hatched from a single batch of eggs. Thus was afforded the opportunity of trying another set of experiments upon a larva which is known sometimes to assume a lichen-like appearance. Furthermore, there was the additional interest of testing larval susceptibility to environment before, during, and after hybernation. The food-plant employed throughout was hawthorn. The present writer is responsible for the starting of the experiments, the arrangements for hybernation, and the comparison of larvæ on September 21st, October 3rd to November 3rd, March 26th, April 27th, May 7th and 25th. The other records were chiefly made by Mr. W. Holland, in much less part by the present writer.

I. *G. quercifolia*.

July 28th, 1893. Fifteen larvæ of *quercifolia* placed with intensely black twigs of the Turkish oak (*Quercus cerris*), intermixed with their food-plant, hawthorn. They were re-fed and examined on the following dates.

August 1st. Twelve larvæ on the green leaves and shoots, 3 on the black twigs. All blackish-grey in colour.

August 5th. Four larvæ on the leaves and shoots, 11 on the black twigs.

August 9th. Three larvæ on the leaves and shoots, 12 on the black twigs.

August 14th. Fifteen larvæ counted; all on the black twigs. The colours were black and white with a little grey.

August 19th. All 15 larvæ on black twigs.

August 22nd. All 15 larvæ on black twigs.

August 31st. All 15 larvæ on black twigs. The larvæ were now much blacker, but white markings were still present.

September 4th. Fifteen counted.

September 7th. Fifteen larvæ on black twigs.

September 9th. Fifteen larvæ on black twigs.

September 14th. Fifteen larvæ on black twigs, 2 blackish, 13 black with white markings.

September 16th. Fifteen larvæ on black twigs.

September 18th. Fifteen counted.

September 21st. Fourteen larvæ on twigs, and 1 little one on leaf. The larvæ were re-fed on September 26th and 30th.

II. *G. quercifolia*.

July 28th, 1893. Fifteen larvæ of *quercifolia* placed with sticks profusely covered with lichen (probably *Ramalina farinacea* was employed throughout) intermixed with their food-plant, hawthorn. They were re-fed and examined on the following dates.

August 1st. One larva on lichen-covered stick; all the others on leaves and leaf-stalks. All blackish-grey in colour.

August 5th. Twelve larvæ on lichen-covered sticks; 3 on food-plant.

August 9th. Fourteen larvæ on lichen-covered sticks; 1 on food-plant.

August 14th. Fourteen larvæ on lichen-covered sticks. Colours black with white and grey markings; the latter larger than on the larvæ of the other experiments.

August 19th. Thirteen larvæ on sticks; 1 on food-plant.

August 22nd. Thirteen larvæ on sticks.

August 26th. Thirteen larvæ on sticks.

August 31st. Thirteen larvæ on sticks. The white and grey markings had now developed to a much greater extent.

September 4th. Thirteen larvæ on sticks.

September 9th. Thirteen larvæ on sticks.

September 14th. Twelve larvæ on sticks. Colours white and grey and black, except in the case of 2 larvæ without any black.

September 16th. Twelve larvæ counted.

September 18th. Twelve larvæ on sticks.

September 21st. Nine larvæ on sticks; 3 on the twigs of hawthorn. At this time of the year it was almost impossible to get a sufficient quantity of the green shoots of the hawthorn, so that darker twigs were sometimes included, and upon these the larvæ occasionally rested. The larvæ never rested upon the lichen itself, but on the surface of the bark between the masses.

The 12 larvæ were re-fed on September 26th and 30th, and on October 3rd and 7th.

III. *G. quercifolia*.

July 28th, 1893. Fifteen of the *quercifolia* placed with red-brown stems of the bramble, intermixed with their food-plant, hawthorn. They were re-fed and examined on the following dates.

August 1st. Only 1 resting on bramble stem, others on leaf-stalks. Blackish-grey in colour.

August 5th. Seven on stems, 5 on green parts of food-plant, 3 on gauze top of cylinder.

August 9th. Thirteen on stems, 1 on green parts of food-plant, 1 missing.

August 14th. Fourteen on stems. Some black with white markings, some grey and some mottled reddish-brown.

August 19th. Fourteen on stems.

August 22nd. One missing, all on stems.

August 26th. Thirteen counted.

August 31st. Thirteen on stems. All were now grey-brown with black and white markings.

September 4th. Thirteen on stems.

September 7th. Thirteen on stems.

September 9th. Thirteen on stems.

September 14th. The colours were now as follows :— 1 brown and grey with white markings, 2 brown with white markings, 3 brown with various shades of grey, 3 grey and brown with white markings, 2 grey with white markings and brown patches, 2 dark grey with white markings.

September 16th. Thirteen counted.

September 18th. Thirteen on stems.

September 21st. Twelve on stems; 1 on hawthorn twig.

They were also re-fed on September 26th, 30th, October 3rd and 7th.

IV. *G. quercifolia*.

July 28th, 1893. Fifteen larvæ of *quercifolia* placed with green leaves and shoots of the hawthorn. They were re-fed and examined on the following dates.

August 4th. Fifteen counted. Blackish-grey in colour.

August 8th. Fifteen counted.

August 14th. Fifteen counted. Rather variable in colour, but somewhat greyer than at first.

August 19th. Fifteen counted.

August 22nd. Fifteen counted.

August 26th. Fourteen counted.

September 1st. Fourteen counted.

September 5th. Fourteen counted.

September 9th. Fourteen counted.

September 13th. Fourteen counted. Colour variable: 3 black and white; 9 grey and black-and-white; 2 grey and brown-and-white.

September 16th. Fourteen counted.

September 18th. Fourteen counted.

September 21st. Fourteen counted. All on the shoots of the hawthorn.

September 26th. Fourteen counted.

October 3rd. Fourteen counted.

October 7th. Fourteen counted.

October 18th. Fourteen counted. Colour unchanged, but rather darker than when last noted. Arranged for hybernation in two muslin bags on the hawthorn tree described on p. 337; one bag containing the 7 darkest, the other the 7 lightest.

FIRST GENERAL COMPARISON (SEPTEMBER 21ST), ALL THE QUERCIFOLIA LARVÆ BEING PLACED UPON A UNIFORM BACKGROUND OF WHITE PAPER.

I. *G. quercifolia*.

As regards the larvæ with black twigs of Turkish oak, it should be noted that the moisture in the glass cylinders had encouraged the growth of small whitish spots of mould upon the dark bark, and it is possible that some effect may have been produced by their presence in the environment.

Of the 15 larvæ, 6 were remarkable for the very slight development of light markings upon the intense black ground-colour: in one larva indeed the light markings were altogether wanting. The remaining 9 larvæ were black, chequered with white markings, which were however far less developed than in the former group which had been with lichen-covered sticks. The ground-colour of these 15 larvæ differed strongly from that of all the others in its deep black shade.

Two of the 6 caterpillars described above, including the uniformly dark one, were selected for painting, together with a representative of the 9 chequered larvæ. The larva without white markings was painted by Mr. Bayzand on September 23rd, and is shown on Plate XVII, fig. 2; the one with minute white markings on September 26th (Plate XVII, fig. 3), and the chequered larva on September 25th (Plate XVII, fig. 1).

II. *G. quercifolia*.

By far the most marked result was seen in the 12 larvæ with an environment of lichen-covered sticks. Not one of the 12 could be mistaken for any larva of the other groups. In the case of 4 larvæ the effects were especially marked, these being of a light colour over nearly the whole of the exposed surface, the black ground-colour quite replaced by a pale brownish tint in one and by grey in the others. The 8 remaining larvæ closely resembled each other, being dark chequered with white; but the ground-colour, although dark, was not black like that of the larvæ with Turkish oak (I), while the white markings possessed a greyish tinge in one larva and a bluish in another.

The 4 larvæ first mentioned were separated from the others for painting at this date, together with the one in which the markings were bluish-white, and another representative of the commonest type of appearance, viz. a dark ground-colour with white markings.

III. *G. quercifolia*.

The ground-colour of all the larvæ with brown bramble-stems was very dusky and brownish. Five of them had a distinct brown patch on each side of the 2nd abdominal segment, partially extending on to the 1st, and another patch on the dorsal surface of the 5th abdominal. The dorsal hump on the 8th abdominal, and in some larvæ the area surrounding its base, were also brown. In the remaining larvæ the light markings were more generally greyish than white, and were often evanescent. Of the first-named 5 larvæ only one had the light markings well developed, and this was selected for painting together with another in which these markings were almost absent. The remaining larvæ were similarly represented by the larva with the white markings best developed and the one in which they were feeblest,

IV. *G. quercifolia*.

The larvæ with green leaves and shoots were very varied, showing tendencies in the direction of all the other groups, but chiefly resembling the chequered black-and-white larvæ with the black twigs of Turkish oak, although the ground-colour was not nearly so dark. A few tended towards the greater development of the light markings which was characteristic of the group with the lichen-covered sticks, while all of them approached the larvæ with the brown stems in the dusky tint of the dark ground-colour. There was no reason for painting any of these larvæ.

ARRANGEMENTS FOR HYBERNATION AND FINAL COMPARISON OF THE QUERCIFOLIA LARVÆ BEFORE HYBERNATION.

I. *G. quercifolia*.

October 3rd. Larvæ with black twigs. It was evident that the larvæ were ready to hibernate. They had eaten very little, and some of them were spinning a foot-hold. The size was that shown on Plate XVII, figs. 1 to 3. A great change had taken place since the last comparison on September 21st: only 3 larvæ instead of 9 were now chequered black-and-white, 6 having become nearly as dark as 5 out of the 6 darkest members of the group. The white patches of the chequered individual painted on September 25th were now far duller and less conspicuous. The larvæ of this and all the other series were specially arranged so as to test for the existence of any susceptibility to the colours of the environment during hibernation. All were enclosed in muslin sleeves upon a large hawthorn tree, with pink double flowers, in the garden of Wykeham House, Oxford. It should be noted that the branches enclosed in the sleeves were very dark, although not so intense a black as the twigs of the Turkish oak.

A. The 3 chequered black-and-white larvæ were enclosed with an abundance of black twigs of Turkish oak.

B. The 5 darkest were similarly placed with lichen-covered twigs.

C. Six dark larvæ, but not quite so dark as the last lot, were similarly enclosed with black twigs.

II. *G. quercifolia*.

October 16th. Larvæ with lichen-covered sticks. Many of these larvæ had also undergone considerable changes since September 21st; so much so indeed in certain cases, that two of the examples set aside for painting had to be changed for others which better represented the appearance borne by the former when they were selected. Of the 4 lightest larvæ on September 21st only one remained greyish (painted October 2nd, shown in Plate XVII, fig. 6); 2 were now of a brownish tinge (painted October 3rd, fig. 4, and October 7th, fig. 9, Plate XVII); while the 4th had become so much darker that another brownish larva was substituted for painting (painted October 6th, fig. 5, Plate XVII). The latter was not, however, as light as any of the other 3 set aside on Sept. 21st. Of the other 2 darker larvæ previously selected for painting, the one with bluish-white spots had altered, and another more like its former appearance was substituted (painted October 9th, Fig. 8, Plate XVII). The remaining 6 dark, white-marked unpainted larvæ had not changed, except that the white marks upon two of them had become smaller and less conspicuous.

These 6 larvæ, with the dark, white-marked one which was painted on October 10th, and is shown on Plate XVII, fig. 7, were divided into two groups for hybernation.

D. Four dark, white-marked larvæ, including the darkest larva of all the 7 with the smallest white spots, were enclosed with lichen-covered sticks.

E. Three dark, white-marked larvæ, including the darkest larva but one of all the 7, were enclosed with black twigs of the Turkish oak.

The 3 lightest larvæ were thus treated.

F. One larva was enclosed with lichen-covered sticks (Plate XVII, figs. 4 or 9).

G. Two larvæ, including the greyish one (Plate XVII, fig. 6), were enclosed with black twigs. The other larva is represented in Plate XVII, figs. 4 or 9.

H. The two remaining larvæ which had been substituted for painting, viz. the brownish larva (Plate XVII, fig. 5), and the dark one with bluish-white marks (Plate XVII, fig. 8), were enclosed with lichen-covered sticks.

III. *G. quercifolia*.

November 3rd. The larvæ with brown bramble-stems were compared and arranged for hybernation. The larvæ were more distinctly brown and more uniformly so than when last compared. The brown patches on three parts of the surface of certain larvæ, viz. the 2nd, 5th, and 8th abdominal segments, were still evident and more distinct than ever. On some individuals they had increased in size. In only a single larva were the light patches at all large and conspicuous. Seven larvæ were very uniform in appearance—dark brown with light brown patches generally present. The remaining 4 larvæ were also dark brown, but 1 was distinctly marked with white, 2 less distinctly marked with brownish-white, while the dorsal surface of 1 was overspread with grey. The latter larva was painted on October 17th (Plate XVII, fig. 12). One of the brownish-white-marked larvæ was painted on October 13th (Plate XVII, fig. 10); and 2 of the 7 first described were painted on September 30th (Plate XVII, fig. 11) and October 16th (Plate XVII, fig. 13).

This group of larvæ was arranged for hybernation as follows:—

I. Four of the 7 uniform larvæ were enclosed with lichen-covered sticks.

J. The remaining 3 were enclosed with black twigs.

K. The 4 more spotted or lighter larvæ were enclosed with brown stems.

FIRST GENERAL COMPARISON AFTER HYBERNATION, MARCH 26th, 1894.

The weather was very warm on March 25th and 26th, and the buds of the hawthorn were well out.

I. THE 14 QUERCIFOLIA LARVÆ ON BLACK TWIGS BEFORE HYBERNATION.

A. *The 3 chequered larvæ with black twigs*.—All three larvæ were quite healthy, and freely moved about when disturbed. Two were at rest on the black twigs, 1 was walking about, probably disturbed by the examination. They had eaten many of the buds, and one had changed

its skin probably since hibernation: the old skin was found in the muslin bag.

B. *The 5 darkest larvæ with lichen-covered sticks.*—All the larvæ were in the same healthy and vigorous condition as those just described, and had eaten the buds of the hawthorn. Every trace of the winter torpor had disappeared, and they moved freely when touched. The larvæ were uniformly dark brown, and quite unaffected by the presence of the lichen. Four were resting on a branch of the hawthorn, while one was on the muslin.

C. *The 6 dark larvæ with black twigs.*—Three were dead and dried up, 2 in the bag and 1 still fixed to a branch of the hawthorn. Of the living larvæ, 2 were fixed to the muslin and 1 to a branch. One larva appeared to be unhealthy. One had changed its skin, and the hawthorn-buds had been eaten. All the larvæ, including the dead ones, were uniformly dark.

It was clear from this comparison that no change had been wrought by the winter surroundings.

II. THE 12 QUERCIFOLIA LARVÆ WITH LICHEN-COVERED STICKS BEFORE HYBERNATION.

D. *The 4 dark, white-marked larvæ, including the darkest of the 12, with lichen-covered sticks.*—These larvæ had evidently eaten, and were healthy and easily disturbed. Three were on branches of the hawthorn, and 1 on a lichen-covered stick, but all had left their silken foot-holds. All retained the appearance they possessed before hibernation: the contrast between dark ground-colour and light markings was weakest in the larva on the lichen-covered stick.

E. *The 3 dark, white-marked larvæ, including the darkest but 1 of the 12, with black twigs.*—All 3 larvæ were on the hawthorn branch, and were in the same condition as the above-described set (D). One was resting on a silken foot-hold, but this was probably accidental, as there was no trace of torpidity. All possessed the lichen-like appearance borne before hibernation.

F. *One of the 3 lightest larvæ, with lichen-covered sticks.*—The larva was resting on the muslin. It was doubtful whether anything had been eaten, but the larva readily moved on disturbance, and was not resting upon a foot-hold. It still remained one of the three lightest larvæ, and had not undergone any change during hibernation.

G. *Two of the 3 lightest larvæ, with black twigs.*—Both larvæ were healthy and irritable; they had evidently eaten. One was resting on the hawthorn branch and 1 on a black twig. They still remained very light, like that described above (F), and were quite unaffected by their dark surroundings during hybernation.

H. *The 2 larvæ—the brownish one and that with bluish-white spots—with lichen-covered sticks.*—It is improbable that anything had been eaten, and these larvæ did not appear to have emerged from hybernation. The one with bluish-grey marks was upon a lichen-covered stick: it was shrunk, and it appeared doubtful whether it would survive. The other was still attached to its foot-hold on the hawthorn branch, and had evidently not moved during the winter. It was very lichen-like, and entirely unchanged by its winter environment.

III. THE 11 QUERCIFOLIA LARVÆ WITH BROWN BRAMBLE-STEMS BEFORE HYBERNATION.

I. *Four of 7 uniformly brown larvæ, with lichen-covered sticks.*—All were healthy and had eaten freely: 3 were on the hawthorn branch, 1 on the muslin. All were distinctly brown.

J. *Three of 7 uniformly brown larvæ, with black twigs.*—One larva was dead, while 2 healthy ones had evidently eaten. Both were on the black twigs, and possessed the same dark brownish ground-colour with brown patches as the 4 last-mentioned larvæ (I).

K. *The 4 most distinctly spotted or lightest larvæ, with brown stems.*—One larva was dead, while 3 healthy ones had evidently eaten. All 3 were on the hawthorn-branch. This set still included the most distinctly white-spotted individuals of the whole 11. It was evident that no change occurred during hybernation.

IV. THE 14 QUERCIFOLIA LARVÆ UPON GREEN LEAVES AND SHOOTS OF THE HAWTHORN.

L. *Seven larvæ enclosed in a muslin bag containing a branch of the hawthorn.*—One larva was dead, 3 were on the branch, 2 on the muslin, while 1 became detached in removing the bag. All had left their foot-holds, with the doubtful exception of one on the branch. All 6 were healthy and irritable, and most of them had evidently fed;

in fact one of those on the branch was eating when the examination was made. The larvæ were on the whole darkish but very variable.

M. *Seven larvæ arranged as in the last set (L).* One larva was dead, 2 were on the branch, and 4 were on the muslin. All had left their foot-holds and were healthy and irritable. They had evidently eaten. Their appearance was similar to that of the set last described.

A complete history of the larvæ of each set, I to IV, subsequent to hybernation, will now be given, followed by an account of the careful comparisons of the whole which were made from time to time, all the larvæ being then placed on a uniform background of white paper.

I. THE QUERCIFOLIA LARVÆ ON BLACK TWIGS BEFORE HYBERNATION.

A. *The 3 chequered black-and-white quercifolia larvæ on black twigs throughout.*

April 7th.—Re-fed. Three black larvæ with small white patches. Unchanged when re-fed on the 10th: all on twigs.

April 16th.—Re-fed. Two larvæ on twigs, 1 on hawthorn: appearance unchanged, as also when re-fed on 20th, 23rd, 27th, and May 3rd: all larvæ invariably resting on the twigs.

May 7th.—Re-fed. One larva unaltered, while 2 had changed skin, and the white markings had become less bright. In one of these the old skin was still adherent anteriorly. This larva was removed to cylinder C (p. 344). The other older darker larva was sent to Lord Walsingham on May 11th.

May 11th.—Re-fed. The single remaining larva was at rest on twig; it was still black with white markings, and was unaltered when re-fed on the 17th, 22nd, and 25th, its position on the twig being noted on the two former dates. It was sent to Lord Walsingham on May 31st.

B. *The five darkest quercifolia larvæ with lichen-covered sticks during and after hybernation.*

April 7th. Re-fed. All 5 larvæ black, 3 of them with white spots.

April 10th. Re-fed. Four larvæ on sticks. Appearance unchanged.

April 16th. Re-fed. Four on sticks, 1 on hawthorn. Only 1 larva was now entirely black, the remaining 4 had acquired large white patches. Two larvæ, including the first-mentioned, were removed to cylinder B¹.

April 20th. Re-fed. All 3 on sticks, appearance unchanged and on sticks, as also when re-fed on the 23rd.

April 27th. Re-fed. Two on sticks, 1 on hawthorn. It was noted that in one of the larvæ the white marks were less developed than in the others.

May 1st. Re-fed. The last-mentioned larva had changed skin and the white markings were reduced to a single anterior pair and were quite small. The 2 others remained as before, and no further change was seen when the 3 larvæ were re-fed on the 3rd, 11th, 17th, 21st, and 25th. They were noted as at rest on the sticks on all these dates, except the first and last. The darkest larva was painted by Mr. Bayzand on May 19th, and is shown in Plate XVII, fig. 14. Of the two others, the one with the more intensely black ground-colour was painted by him on the 22nd, and is shown in fig. 15 of the same plate. Both these figured larvæ were sent to Lord Walsingham on May 25th, and the third was sent on May 31st.

B¹. *The two quercifolia larvæ separated from cylinder B on April 16th.*

April 16th. The larvæ were respectively entirely black, and black with white patches.

April 20th. Re-fed. Both on sticks, colour unchanged. Similar results were noted when re-fed on the 23rd and 27th.

May 1st. Both larvæ had apparently changed skin. The darker one had gained a pair of small white marks anteriorly. On May 5th the larvæ were brought back from London. No further change.

May 11th. Re-fed. The black-and-white larva was sent to Lord Walsingham. The single dark larva, on stick; appearance unchanged. Similar notes on the 17th, 22nd, and 25th, except that it rested on the hawthorn on the first-named date, and its position was not recorded on the last-named. The larva was sent to Lord Walsingham on May 31st.

C. *Three dark quercifolia larvæ (out of 6) on black twigs throughout.*

April 7th. Re-fed. Two larvæ dead. The third at rest on twig; black. When re-fed on the 10th it was on twig and unchanged.

April 16th. Re-fed. At rest on twig. It had changed skin and was black with a few whitish spots. When re-fed on the 21st, 23rd, 27th, and May 3rd it was unchanged, and on each occasion resting on a twig.

May 7th. Re-fed. At rest on twig; unchanged. A rather darker larva from cylinder A was added. Part of the skin of the previous stage was adhering to the anterior part. When re-fed on the 11th, 17th, 21st and 25th, these larvæ were unchanged in appearance. Upon all dates except the last it was noticed that they were both upon twigs. Both larvæ were sent to Lord Walsingham on May 31st.

II. THE QUERCIFOLIA LARVÆ ON LICHEN-COVERED STICKS BEFORE HYBERNATION.

D. *Four dark, white-marked quercifolia larvæ, including the darkest of II, on lichen-covered sticks throughout.*

April 7th. Re-fed. Four larvæ, of which one appeared to be unhealthy. All were darkish with large white patches.

April 10th. Re-fed. One larva had died, 3 upon sticks. Two had changed skin, 1 remaining unaltered, the other with a further extension of the white patches.

April 16th. Re-fed. Two larvæ upon sticks, 1 upon hawthorn. All were dark with large white patches, and 1 larva was very small.

April 21st. Re-fed. The 2 larger larvæ on sticks, the small one on hawthorn. The former dark grey and pale greyish-brown respectively; both with very large white patches. The small larva was brownish-grey with pale marks. When re-fed on the 23rd all were on sticks and unchanged, as also on the 26th, except that the small larva was on the hawthorn.

May 3rd. Re-fed. The pale greyish-brown larva had changed skin and was now a darker blackish-brown, with large pale markings. The other larvæ were unaltered.

May 11th. Re-fed. Two on sticks, the third, the large

dark grey larva, having been sent to Lord Walsingham on this date. The remaining large larva was dark brown with large yellowish markings; the small larva had changed its skin and was bluish-grey. The larvæ were re-fed on the 17th and 22nd, when they were on sticks and unchanged in appearance. The larger larva appeared to be unhealthy on the 22nd and died on the 23rd.

May 15th. Re-fed. The colour of the small larva was unchanged, as also on June 1st and 7th. It continued to grow slowly without further change, and finally spun up on July 28th.

E. *Three dark, white-marked quercifolia larvæ, including the darkest but one in II, on black twigs during and after hibernation.*

April 7th. Re-fed.

April 10th. Re-fed. All 3 larvæ on twigs. Two larvæ had changed skin, but the appearance of all 3 remained the same, viz. black with very conspicuous white markings. They were unchanged and at rest on the twigs when re-fed on the 16th, 21st and 23rd.

April 26th. Re-fed. All on twigs. The dark colour of the larvæ appeared to have become more distinctly grey—dark grey in two cases, grey in the third. As before, the dark shade was combined with white markings.

May 2nd. One dark grey and white larva had changed skin and was blackish and white.

May 11th. Re-fed. The largest larva with a rather darker ground-colour than others was sent to Lord Walsingham. The 2 remaining larvæ on twigs; both blackish and white. Re-fed again on the 17th, when they were on the twigs and unchanged. The smaller larva did not seem healthy and had not grown like the other. The larger larva, the darkest of all in set II, was painted on May 17th, and is represented in Plate XVIII, fig. 4.

May 22nd. Re-fed. Two larvæ on twigs. The appearance unchanged, but neither looked healthy. The larger larva died on the 25th and the smaller on June 1st.

F. *One light quercifolia larva on lichen-covered sticks throughout.*

April 7th. Re-fed. White and pale grey.

April 10th. Re-fed. On stick. The larva had changed its skin, and had become white with markings of two

shades of brown. It was re-fed on April 16th, 21st (markings of two shades of pale brown), and 23rd, and was always found on sticks with appearance unchanged.

April 26th. Re-fed. On stick. The larva was now white with grey and brownish markings. On May 3rd it was re-fed, the appearance being unchanged.

May 7th. The larva had changed skin; the white parts had become yellower. It was re-fed on May 11th, 17th, and 22nd, and was noted as at rest on stick on the 11th and 22nd. It remained to the end of a yellowish-white with markings of grey and brown.

May 25th. The larva was painted by Mr. Bayzand and is shown in Plate XVIII, fig. 3. It was sent to Lord Walsingham on the same date.

G. Two light quercifolia larvæ on black twigs during and after hybernation.

April 7th. Re-fed. Both lichen-like.

April 10th. Re-fed. Both at rest on twigs. One had changed skin, and the greyish markings had become rather darker. Both were at rest on twigs with appearance unchanged when they were re-fed on the 16th.

April 21st. Re-fed. Both on twigs. One larva was white with pale grey markings, the other creamy-white with markings of a brownish-grey. Unchanged and on twigs when re-fed on the 23rd.

April 26th. Re-fed. Both on twigs. The white colour of the larva first mentioned on the 21st had gained a faint bluish tinge. The other larva unchanged.

May 5th. Re-fed, after having been brought back from London. The creamy-white larva had changed skin and was rather paler in tint. Both were on twigs and unchanged when re-fed on the 11th. The creamy-white larva was painted by Mr. Bayzand on the 14th, and is shown in Plate XVIII, fig. 1.

May 17th. Re-fed. Both on twigs. One larva large and pale creamy-white with greyish-brown markings. The other much smaller, white with bluish-grey markings, but with tints duller than they were formerly. It had not grown much, nor changed its skin. Both larvæ were unchanged in appearance, and were resting on twigs when they were re-fed on the 22nd. The creamy larva was sent to Lord Walsingham on May 25th. The smaller bluish-

grey larva was painted on May 28th, and is shown in Plate XVIII, fig. 2. It was sent to Lord Walsingham on May 31st.

H. *The brownish quercifolia larva and the larva with bluish-white marks on lichen-covered sticks throughout.*

April 7th. Re-fed. One larva dead; the other grey and white. The larva was re-fed on the 10th, 16th, 20th, 23rd, 26th, and on May 3rd. Its appearance remained unchanged. On all these dates except the last it was noted that the larva was at rest on the sticks. On May 5th it was dead.

III. THE QUERCIFOLIA LARVÆ ON BROWN BRAMBLE-STEMS BEFORE HYBERNATION.

I. *Four uniform quercifolia larvæ on lichen-covered sticks during and after hybernation.*

April 7th. Re-fed. All 4 dark brown, 2 rather darker than the others.

April 10th. Re-fed. All 4 at rest on sticks: 2 unchanged, and 2 had changed skin, becoming respectively dark grey with white patches and blackish-grey with white patches and brown marks.

April 14th. Re-fed. Larvæ on sticks. The larger ones unchanged. The 2 smaller had now changed skin, becoming respectively very dark blackish-brown with white marks, and dark brown mottled with pale grey.

April 16th. Re-fed. Larvæ on sticks. The 2 larger darker larvæ were now placed in another cylinder. The two remaining were respectively—mingled shades of dark and light grey with brown patches, and a uniform grey with large white patches. These 2 larvæ were re-fed on April 21st and 23rd without change. They were always at rest on the sticks.

April 26th. Re-fed. Both larvæ on sticks. One larva retained same appearance, grey with brown patches; the other was of a pale brownish-grey with paler marks.

May 1st. The latter larva had become of a much darker brownish-grey with brown and pale marks. On May 3rd they were re-fed, and both were on sticks: appearance unchanged.

May 11th. Both larvæ on sticks. The last described

larva unchanged. The other had now also darkened, becoming blackish-grey with paler marks. The larvæ were re-fed on May 17th, 21st, and 25th, without further change in appearance. It was noted that they were at rest on the sticks on the 17th and 21st. On May 31st both larvæ were sent to Lord Walsingham.

I¹. *The two larger darker quercifolia larvæ separated from I on April 16th.*

April 16th. One larva was now blackish-brown with white marks, the other very dark grey with white and brown marks.

April 21st. Re-fed. One larva on sticks, 1 on twigs of hawthorn. Appearance unchanged, as also on April 23rd and 26th, when they were re-fed and both found on sticks.

May 1st. The dark grey larva had changed skin and become blackish-brown with pale and brown spots. On May 3rd they were re-fed and found unchanged in appearance on the sticks.

May 11th. The larva with pale and brown spots was sent to Lord Walsingham. The remaining larva was at rest on stick, and blackish with two pale marks. It was re-fed on May 17th (on stick) and 25th. On the 31st it was sent to Lord Walsingham. There was no further change in its appearance.

J. *Two uniform quercifolia larvæ on black twigs during and after hibernation.*

April 7th. Re-fed. One larva purplish-brown and black, the other had changed skin and was black with small white patches and minute brown points. Both were resting on twigs and unchanged in appearance when re-fed on the 10th.

April 16th. Re-fed. Both on twigs. The purplish-brown and black larva appeared to be even darker, the other unchanged. Both were on twigs and unaltered when re-fed on 21st and 23rd.

April 26th. The black larva with small white patches and minute brown points was dying.

April 27th. The last-mentioned larva was dead. The other purplish-black larva was at rest on a twig.

May 1st. The larva had changed skin, and was black with

a pair of small white marks. It was on a twig unchanged when re-fed on the 3rd.

May 25th. The larva was sent to Lord Walsingham. Mr. Bayzand completed his painting of it on the 11th, and the larva is represented on Plate XVIII, fig. 6.

K. *Three of the more spotted or lighter quercifolia larvæ on brown bramble-stems throughout.*

April 7th. Re-fed. One larva brown, 1 brown with few white marks. The third grey-brown one had changed its skin and become brown-grey with white patches.

April 10th. Re-fed. Larvæ resting on stems. The brown larva had become brown and very dark grey with white patches. The other two remained the same.

April 16th. Re-fed. Larvæ resting on stems. The brown larva with a few white marks had become darker, and was now black along the median dorsal area and very dark brown on the sides: the white patches large. The two other larvæ remained the same.

April 20th, 23rd, and 27th. The larvæ were re-fed on each of these dates, and were invariably found upon the stems. The appearance was unchanged.

May 1st. One of the brownish-grey larvæ changed its skin, becoming rather browner in shade.

May 3rd. Re-fed. Three larvæ resting on stems. Appearance unchanged.

May 11th. Re-fed. Two larvæ on stems. Appearance unchanged. Mr. Bayzand finished painting the brownest larva which is represented on Plate XVIII, fig. 5. The brownish-grey larva sent to Lord Walsingham for preservation. Another brown one was sent on the 12th.

May 17th, 22nd, and 25th. The single remaining larva was re-fed on each of these dates. It was noted as at rest upon a stem except on the 25th. Its appearance was the same on all occasions, viz. blackish with pale grey marks and brown spots. It was sent to Lord Walsingham on May 31st.

IV. THE QUERCIFOLIA LARVÆ ON LEAVES, TWIGS, OR SHOOTS OF THE HAWTHORN THROUGHOUT.

L

April 7th. Re-fed. One brown larva dead. Appearance of others unchanged, viz. 3 brown and 2 blackish-brown.

April 10th. Re-fed. Three larvæ unchanged. One brown and 1 blackish-brown larva had changed skin and become blackish-grey with large white patches.

April 16th. Re-fed. The two largest larvæ last described removed to another cylinder, L¹. The three others unchanged. One of two smaller brown larvæ appeared unhealthy.

April 20th. Re-fed. One larva had changed skin and grown much. Of the others, neither of which had changed skin, one was dead and one appeared to be dying.

April 23rd. The single healthy larva was brownish-black with white marks.

April 27th. The small larva was dead. The appearance of the other unchanged, as also on May 3rd and 11th, when it was again re-fed. On May 17th the larva had died.

L¹

The two larvæ separated from L on April 16th were re-fed and examined on April 21st, 23rd, and 27th, the appearance remaining the same throughout, viz. dark grey with large white patches. On May 3rd the larger of the two larvæ looked sickly; on May 5th it was dead and the smaller one seemed unhealthy. The latter died on May 7th.

M

April 7th. Re-fed. Five larvæ alive, all greyish-brown. One of two unhealthy-looking larvæ had died.

April 10th. Re-fed. Four larvæ unchanged; the fifth had changed skin and had developed larger white patches.

April 16th. The 2 largest larvæ were now separated and placed in another cylinder, M¹. The remaining 3 were brownish-grey, 2 of them with pale patches. The smallest was browner than the others and appeared to be unhealthy.

April 21st. Re-fed. The last-mentioned larva was dead; the others unchanged in appearance although one had changed skin during the interval.

April 23rd. Re-fed. Unchanged.

April 27th. Re-fed. One larva had become darker, viz. blackish-grey with white patches. The larvæ were re-fed and compared on May 3rd, 11th, and 17th, without change in appearance.

May 22nd. Re-fed. The brownish-grey larva had died, the darker one unchanged.

May 25th. The last-named larva had died. Neither of these larvæ had grown large.

M¹

The 2 largest larvæ separated from M on April 16th. Both were greyish-brown with distinct white patches.

April 21st. Re-fed. Unchanged. The larvæ were also re-fed on the 23rd, 27th, May 3rd, 11th, 16th, and 22nd, and examined on each occasion. The appearance remained the same throughout. On the 25th both were sent to Lord Walsingham.

SECOND GENERAL COMPARISON AFTER HYBERNATION.

April 27th, 1894. The larvæ were carefully compared and were all placed upon a background of white paper. Nearly all of them were sluggish, probably preparatory to the last ecdysis.

I. THE QUERCIFOLIA LARVÆ WITH BLACK TWIGS BEFORE HYBERNATION.

A. *The three chequered larvæ with black twigs.*—These larvæ were unchanged and still remained the lightest of the whole of series I. Hence the black twigs had produced no effect during hybernation.

B. *The five darkest larvæ enclosed with lichen-covered sticks during hybernation.*—One was very dark, the darkest of the whole group; 1 was dark with faint light spots; 3 were black chequered with white markings, which however were less developed than in A.

It is possible that these last-mentioned three larvæ may indicate some susceptibility to the effect of the lichen-covered sticks after they were enclosed upon the tree and before the commencement of hybernation.

C. *The six dark larvæ with black twigs.*—Only one larva was alive, and this was dark with very faint dull white spots.

All the above described 9 larvæ were healthy and well up to the average size.

II. THE QUERCIFOLIA LARVÆ WITH LICHEN-COVERED STICKS BEFORE HYBERNATION.

D. *The four dark, white-marked larvæ, with lichen-covered sticks.*—Three larvæ were alive and unchanged: one was very small.

E. *The three similar larvæ, with black twigs.*—These also were practically unchanged and like D. One of these was now the blackest larva, but the smallest in D was almost exactly the same. It is possible that some *very slight* effect was produced by these black twigs before hybernation.

F. *One of the three lightest larvæ with lichen-covered sticks.*—The larva was quite unchanged.

G. *Two of the three lightest larvæ with black twigs.*—No effect had been produced by the black surroundings. The bluish-grey larva remained very distinct.

H. *Two larvæ with lichen-covered sticks.*—The brownish larva had died. The other still remained the darkest individual of the lighter part of the group (F, G, H) as it was when the arrangements for hybernation were made.

Comparing these two important groups I and II as a whole, it was seen that the lightest larva of I (in A) was almost precisely similar to the darkest of II (in E):—in fact they could not have been distinguished as regards the size of the light patches. On the other hand, the larva in I was healthy and of the average size, while that in II was rather small. The smallest in D was not considered in this comparison, as it had grown but little and was a stage behind the others. Its light patches, although very dull and grey, were almost exactly the same size as those of the darkest larva in D. The remaining nine larvæ in II were all large and healthy, and much lighter than the lightest larva in I.

III. THE QUERCIFOLIA LARVÆ WITH BROWN BRAMBLE-STEMS BEFORE HYBERNATION.

Comparing these as a whole with sets I and II it was obvious that the lightest of them was distinctly darker than the darkest of the group just described (II) and exposed to lichen before hybernation. The larvæ were perhaps as dark as those in group I, exposed to Turkish oak before hybernation, but they were not so black, and, except in two larvæ, the light markings were less white, being greyish and clouded over.

I. *The four uniform dark larvæ with lichen-covered sticks.*—Two larvæ were very dark with a dull blackish ground-

colour. The two others were not so dark and bore brown points and patches, which tended to fuse at their edges with the dark greyish ground-colour.

J. *The three similar larvæ with black twigs.*—Only one larva was alive, and this was rather darker than the darkest of the set just described (I), having a dull blackish ground-colour. One dead larva had a very black ground-colour with brown dorsal points and distinct although small white patches. It is probable that some slight effect was produced by the black twigs just before hybernation began.

K. *The four lightest and most distinctly spotted larvæ, with brown twigs.*—Three larvæ were alive. The smallest one possessed the blackest ground-colour and the whitest patches of any in the whole series (III). The other two closely resembled the two lighter larvæ in I.

IV. THE QUERCIFOLIA LARVÆ UPON GREEN LEAVES AND SHOOT OF THE HAWTHORN.

L, M. There was no distinction between the two lots. The larvæ, as before hybernation, presented a great range of variation, but the ground-colour was upon the whole greyish. The lightest individual was rather lighter than the darkest of those upon lichen before hybernation (II), while the next in order was about the same as the darkest of II. Four others were rather less light, while a fifth was a distinctly dark form. Hence the set was upon the whole intermediate between I and II and distinctly lighter than III.

April 28th. The length of all those larvæ which had ceased to feed preparatory to a change of skin was about 56·0 mm. A few days later the cast skins were examined, and were seen to possess the white markings as well as the dark ground-colour. Hence these characters are in part, if not entirely, cuticular in position.

THIRD GENERAL COMPARISON OF THE LARVÆ MADE AFTER HYBERNATION, MAY 7TH.

I. THE QUERCIFOLIA LARVÆ WITH BLACK TWIGS BEFORE HYBERNATION.

A. *The 3 chequered larvæ with black twigs.*—Two larvæ were dark, and 1 black chequered with white markings, which were larger than those of any other larvæ in I, but

much smaller than any in II, except the small larva in E and 1 in D.

B. *The 5 darkest larvæ with lichen-covered sticks.*—Three larvæ, 1 of which was changing its last skin, were black chequered with white markings, which were not quite so large as those of the larva in A. Two larvæ were very dark and unspotted.

C. *The single dark larva with black twigs* was changing its last skin, and was still dark.

Hence probably no effect had been produced by the surroundings to which the larvæ had been exposed since hybernation.

II. THE QUERCIFOLIA LARVÆ EXPOSED TO LICHEN-COVERED STICKS BEFORE HYBERNATION.

D. *The 3 dark, white-marked larvæ with lichen-covered sticks.*—Two larvæ were large in the last stage. One of them became much darker after changing its last skin, but still remained black with light markings. The effects of their dark and light tints were more brownish and yellowish, and on the whole darker than those of the 2 large larvæ in E. In fact, a comparison of D and E did not support the conclusion that the larvæ were sensitive to their environment after hybernation.

The small larva in D which had lagged behind the others had changed its skin and was rather lighter. It was still in an earlier stage than any of the others, but apparently healthy.

E. *The 3 similar larvæ with black twigs during and since hybernation.*—Two larvæ were large in the last stage and remained black-and-white. The third larva was smaller and had been injured. It was probably unable to change its skin in consequence.

F. *One of the lightest larvæ with lichen-covered sticks throughout.*—This larva was in last stage, and its light markings had become much darker in tint, being of a yellowish-brown colour.

G. *Two of the lightest larvæ with black twigs during and since hybernation.*—The lighter of the 2 remained about as in the previous stage; the other, the bluish-grey larva, had not yet changed its last skin, but was apparently

rather darker. These 2 larvæ were upon the whole somewhat lighter than those in F and H.

H. *The larvæ with bluish-white spots exposed to lichen-covered sticks throughout.*—This larva was dying. It was now lighter than the larva in F, but this difference was entirely due to changes in the latter.

III. THE QUERCIFOLIA LARVÆ WITH BROWN BRAMBLE-STEMS BEFORE HYBERNATION.

I. *The 4 uniform larvæ with lichen-covered sticks during and since hybernation.*—Three larvæ were in the last stage, 2 of them brownish with small white spots like those in K, but with the ground-colour darker. The 3rd was considerably darker. The 4th larva was changing its skin. It possessed a deep brownish-black ground-colour, which appeared to be overspread with grey.

J. *The uniform larva with black twigs during and since hybernation.*—The larva was very large in the last stage, and very uniformly dark and unspotted, although rather less black than those which had been exposed to black twigs before hybernation (I).

K. *The 3 spotted or lighter larvæ upon brown stems throughout.*—Two larvæ in the last stage were dark brownish with small light patches. The third, in the last stage but one, was more black-and-white, resembling the larvæ which had been exposed to black twigs before hybernation (I).

Compared as a whole the larvæ of I were blacker than III, although these were very dark. The latter were distinguished by greyish-brown shades absent from the ground-colour of I. The light patches, when present, were distinguished in III by a brownish tinge, and were more clouded and less distinct than in I.

Comparing carefully the darkest larva of II (viz. the 4 darkest in D) with those of I, it was seen that the pale patches were of the same size as those of the larvæ in which they were most developed of all exposed to black twigs (viz. the lightest larvæ in A). But although the patches were of the same size, those of the former were yellowish-brown and clouded, and those of the latter white. The ground-colour of the larva in II was, however, much lighter, being a brownish-black, than that of the lightest larva in I. Hence the darkest larva in II was distinctly darker

than the lightest in I as regards its pale patches, but distinctly lighter as regards its ground-colour. And this comparison only holds for a single exceptional dark larva. All others in II were far lighter than any in either I or III.

IV. THE QUERCIFOLIA LARVÆ EXPOSED THROUGHOUT TO THE LEAVES AND SHOOTS OF THE HAWTHORN.

Only 6 larvæ remained alive, and of these but 2 were in the last stage. Four larvæ possessed a ground-colour very like that of series III, but the white patches were far larger, and tended to spread as a greyish shade down the sides. The light patches were, however, much smaller than in the larvæ of series II. One of the smallest larvæ was dark with very small white patches, like one of the darkest of III. A dying larva, unable to change its skin, was intermediate between this latter and the 4 first-mentioned larvæ.

The colours of these larvæ in series IV seem to have been influenced by the brownish and greyish twigs and shoots of the hawthorn.

LAST GENERAL COMPARISON OF THE QUERCIFOLIA LARVÆ AFTER HYBERNATION, MAY 25TH.

Of series I it was recorded that the single larvæ in A and 2 in B were black with conspicuous white markings; while 1 in B, 1 in B¹, and 2 in C were dull black with only a pair of small inconspicuous white markings.

Of series II nothing is recorded which is not contained in the description of cylinders D to G.

Of the 4 larvæ then remaining in III it was noted that the larvæ in K much resembled the black-and-white ones in A and B: while the 3 in I and I¹ were dull blackish with the pale markings very inconspicuous.

Only 2 larvæ remained alive in IV. The brownish ground-colour of both was much clouded and overspread with grey, and the pale patches tended much to spread downwards, becoming grey and clouded especially towards the ventral surface.

TRANSFER EXPERIMENTS WITH THE LARVÆ OF AMPHIDASIS BETULARIA IN 1896.

A female moth, captured at Oxford, laid a small batch of eggs, which provided the material for the following

experiments, undertaken in order to attempt to ascertain the susceptible stages of this highly-sensitive larva.

The experiment started on May 10th, when the young larvæ were first fed upon the leaves of *Populus nigra*, all dark twigs and branches being at first rigidly excluded. It must be remarked, however, that for a few days after May 10th the leaves had only just expanded and were somewhat brownish. Various sets of larvæ were withdrawn from the stock, and the transference experiments were then conducted in the following manner. All measurements were taken when the larvæ were stretched and straight. A convenient summary of the results of the following experiments will be found in the table on page 319.

A. A. betularia.

May 16th. Twenty *betularia* larvæ at the end of the 1st stage, and nearly all changing the first skin, and 5.0 mm. long, were transferred from green to black surroundings (the twigs of the Turkish oak). Up to this date the green leaves of *P. nigra* upon which they had been placed on May 10th were somewhat brownish, because the buds had only just opened.

May 20th. The larvæ were examined from time to time between the 16th and this date, and had always been found upon the leaves and never upon the twigs. On the 20th every single larva was found upon the leaves. They even avoided the stem of the food-plant. Ten larvæ changing the 2nd skin, and 8.5 mm. long, were re-transferred into green surroundings (*A*¹). The 10 remaining larvæ had attained various degrees of development in the 2nd stage, 3 being at the end of it, but not yet changing the 2nd skin. From this date to the 29th these 10 larvæ were fed upon Balsam Poplar, but from the latter date onwards upon *P. nigra*.

May 25th. Only 1 on the twigs, the rest on the leaves. One larva was changing the 2nd skin, and none had yet entered the 3rd stage.

May 29th. Two larvæ on the twigs, and both these were changing the 3rd skin. Of the rest 1 was changing the 3rd skin and 12.5 mm. long, and 2 had just changed it. These 5 were re-transferred to green surroundings (*A*²). The remaining 5 were in the 3rd stage, 4 nearly at the end of it, and 1 very small.

May 31st. Only 1 on twigs. Four changing 3rd skin,

the 5th still small in the 3rd stage. The black twigs were removed at this date, and the 5 larvæ by this means re-transferred to green surroundings.

June 2nd. Four in 4th stage, and 1 nearly at the end of 3rd stage. Four distinct medium brown colour; 1 very black.

June 5th. One changing 4th skin and light reddish-brown; 2 in 4th stage, both darkish brown; 1 at beginning of 5th stage and medium brown; the 5th small one was only 9.0 mm. long.

June 14th. One small in 6th stage, and dark brown with distinct grey markings prominent on it; 1 changing 5th skin and light brown with ventral surface rather greenish; 2 at end of 5th stage, 1 intermediate and 1 similar to but rather darker than the larva changing its skin.

June 20th. Four in 6th stage, 2 dark, overspread with greyish, 1 green with brown dorsal line and lateral patches, 1 dark form becoming greenish on the sides.

June 26th. One dark larva mature and removed.

July 2nd. The green larva and the one with greenish sides mature and removed. The remaining larva was very dark, with distinct sharply-marked pale yellowish spots on its sides, and one on each side of the dorsal surface of each segment.

July 12th. The larva described above had been accidentally drowned.

CONCLUSIONS.

The effect of the dark surroundings is evident. The green environment of the three last stages was doubtless the cause of the greyish tint, the greenish sides, and the yellowish spots on the 3 dark larvæ. In the case of the 4th larva the effects of the latter surroundings were predominant, although the larva still retained strong traces of its earlier environment in the brown markings. Comparing this result with that of A¹, the relative unimportance of environment in stage II becomes clear.

A¹. *A. betularia*.

May 20th. The 10 *betularia* larvæ re-transferred from black into green at the end of the 2nd stage, changing the 2nd skin, and 8.3 mm. long.

From this date to the 29th the larvæ were fed upon Balsam Poplar, and then again upon *Populus nigra*.

May 25th. Most of the larvæ were changing the 3rd skin, and all were apparently dark.

May 29th. All had changed the 3rd skin except 2, which were changing it. All were dark brown except the 2 latter, which, together with 1 which had just changed, were light brown. The average length was 14.25 mm.

June 2nd. Four were changing the 4th skin; 5 were at various points in the 4th stage, with an average length of 20.75 mm.; 1 was in the 5th stage. All were brown, although not very dark.

June 5th. Four were changing the 5th skin, 33.0 mm. long, and 1 at end of 5th stage. The latter was medium brown, the others 3 light brown and 1 green with light brown markings. The remaining 5 were much smaller, being all in the 4th stage, 3 dark brown and 2 light brown.

June 14th. Five were nearly mature, 2 green sprinkled with distinct greyish dots much more numerous in the larger larva, which was practically mature and 55.0 mm. long. The ground-colour of this latter larva was bright green, the dorsal tubercles dark grey. Of the other 3 large larvæ, 1 was very light grey, almost whitish with darker dots and mottling, 2 were much darker, blackish rather than brown, with light grey markings. The largest of the set of smaller larvæ was changing its 5th skin and greenish-brown, 1 smaller in the 5th stage was green with dorsal brown line, 1 smaller still, chocolate brown. Two larvæ were still quite small, viz. 12.25 mm., and probably still in the 4th stage. Both were dark brown, but they appeared to be unhealthy.

June 15th. The greenest, the whitish, and 1 dark larva had become mature and were removed.

June 20th. One green larva mature and removed. Two in 6th stage, 1 dark with greyish markings not greatly developed, 1 intermediate, brownish-green; 1 changing 5th skin, green, 2 in 5th stage and lightish brown.

June 22nd. The dark larva in 6th stage mature and was removed. Two larvæ in 6th stage, 1 on green side of intermediate, viz. green clouded over but not entirely obscured by brown, 1 distinct green with a brown dorsal line and a little brown on the sides. Of the 2 smaller larvæ, 1 was in the 5th stage and brownish-green, 1 in the 4th and light brown.

June 26th. The brownish-green larva in the 5th stage was dead. The 2 large ones as last described.

July 2nd. The greenish intermediate larva had become mature and was removed. The distinct green one was very large, being 64.6 mm. long. The green ground-colour was somewhat dull, and the brown dorsal line broad but not dark. The remaining larva was in the 5th stage and intermediate.

July 12th. The last-mentioned larva was dead. The other had pupated.

CONCLUSION.

The effect of a dark environment during the 2nd stage alone, although slight, is very remarkable. The grey which overspread the green forms may be compared to the grey patches on the dark form in this and so many of the other experiments.

A². *A. betularia*.

May 29th. The 5 *betularia* larvæ re-transferred to green surroundings after they had been in black during the 2nd and 3rd stages.

May 31st. All 5 larvæ were advancing in the 4th stage, and all dark or distinct brown.

June 2nd. Two larvæ were changing the 4th skin and 22.0 mm. long; the 3 others advancing in the 4th stage. Appearance unchanged.

June 5th. One larva changing 5th skin and medium brown; 2 half-grown in 5th stage and 1 nearly at end of it; 2 dark brown, 1 of the larger pair light brown. The 5th larva in 4th stage and dark brown.

June 14th. Four approaching the end of the 6th stage; 2 very black and 2 similar, except that the ground-colour was overspread with light grey, in one case slightly, in the other thoroughly. The latter was nevertheless a darkish larva. The 5th larva was changing the 5th skin, and green with a brown median dorsal line.

June 15th. One dark larva had become mature and was removed.

June 20th. One dark larva mature and removed. The remaining 3 larvæ were all in the 6th stage. The grey colour of one of the dark larvæ was still very distinct. The brown dorsal line was pronounced upon the green larva.

June 26th. The 2 dark larvæ mature and removed. The 5th larva had now become a typical and distinct bright green form, the brown dorsal line having almost disappeared.

July 2nd. The green larva mature and removed.

CONCLUSIONS.

This is a deeply interesting little set, showing the effect of the dark surroundings persisting unaltered in the 2 larvæ which were first to pupate, the green environment producing some effect in the greyness overspreading the next 2, and predominating altogether in the last.

B. *A. betularia*.

May 20th. The 51 *betularia* larvæ remaining in the stock, with green leaves and shoots of *Populus nigra*, were carefully examined. Two larvæ had just entered the 3rd stage, having changed the 2nd skin, 5 were small in the 2nd stage, while all the rest were changing the 2nd skin, and thus at the end of the 2nd stage. Twenty of these latter were transferred to a cylinder (B¹) with an abundance of black twigs of the Turkish oak, while the remainder were put back into the green environment. From this date to the 25th all the larvæ were fed on Balsam Poplar.

May 25th. Thirty larvæ counted at this date. Of these, 15 changing the 3rd skin were transferred to a cylinder (B²) with black twigs. The remaining larvæ were smaller, but even in the 3rd stage a small proportion of green individuals had begun to appear among the brown. All the larvæ were fed on *Populus nigra* from this date (May 25th) onwards.

May 29th. The 15 larvæ remaining in the green environments were mostly at the end of the 3rd stage and many were changing the 3rd skin. They were mostly light brown but some were green.

June 2nd. Six larvæ had reached the end of the 4th stage, although they were not changing their skins. Of these 5 were green with slight traces of brown, while the 6th, although green, retained a larger amount of the darker shade. Six larvæ were smaller, having reached various points in the 4th stage. Of these 2 were green with slight traces of brown, while four were brownish-green or light greenish-brown. Three larvæ were still in the 3rd

stage, and of these the smallest was dark brown while the other 2 were light greenish-brown.

June 3rd. The five largest larvæ were changing the 4th skin, and were placed in a cylinder (B³) with black sticks. Their colour was as described on June 2nd, and their length 20.5 mm. The colours of the remaining 10 larvæ had not altered.

June 5th. Only 9 larvæ were found. Two larvæ were in the 5th stage and bright green. Five were more or less advanced in the 4th stage, and were distinctly green with a variable degree of development of brown patches. Two were much smaller in the 4th stage and light greenish-brown in colour.

June 20th. Three larvæ were large in the 6th stage, and all very bright green with only a trace or no trace at all of a brownish tint along the median dorsal line. The other 6 larvæ were not noted on this date.

June 26th. Only 8 larvæ were found. Two of the largest green larvæ had become mature, and were removed for pupation. The remaining 6 were of various sizes, but all were bright green except one.

July 2nd. One green larva was mature and was removed. Three were in the 6th stage, 2 bright green, one of them with a little brown on the sides and a brown dorsal line; the 3rd was intermediate, with a brown dorsal line, and green and brown patches alternating on the lateral surfaces. One was changing the last skin and one in the 5th stage, both bright green.

July 12th. One green larva mature and removed. The 2 small ones were dead. Of the two remaining larvæ in the 6th stage 1 was bright green and 1 intermediate.

CONCLUSIONS.

The only point which calls for remark is the occurrence of a single intermediate larva. This was a probable result of the large numbers of the young larvæ in a single cylinder: so that some effect in a specially susceptible individual followed from the presence of other young brownish caterpillars.

B¹. *A. betularia*.

May 20th. The 20 *betularia* larvæ changing the 2nd skin transferred from green leaves and shoots to an environment

of black twigs. The larvæ were of a very uniform length of 8.5 mm.

May 25th. Six were found on the black twigs, the rest on the leaves. Ten larvæ, all about 140 mm. long, at the end of the 3rd stage, and mostly changing the 3rd skin, were transferred to green surroundings (C). The remaining larvæ were fed on Balsam Poplar from May 20th until the 29th. Green forms had begun to appear among the brown.

May 29th. Only 1 on black twigs. Seven larvæ were at the beginning of the 4th stage, 6 dark and 1 greenish. Two were changing the 3rd skin and 1 nearly mature in the 3rd stage.

June 2nd. Four larvæ on the twigs. Two were changing 4th skin, and 8 at various degrees of development in the 4th stage. All brown and the largest larvæ very dark brown.

June 3rd. Only 1 on the twigs. Two had now changed 4th skin on the 2nd, and were transferred to green surroundings (C¹): 1 was very black, the other a medium brown.

June 4th. Three on twigs. All larvæ in 4th stage, all brown of various shades: those on the twigs very black.

June 5th. Only 1 on twigs and that a light brown one. One light brown larva changing 4th skin and transferred to green surroundings (C¹). Five in the 4th stage, including 1 dark brown larva which had just died, 1 in 3rd stage. All brown (more or less dark).

June 7th. Two on twigs, dark and medium brown. The latter was changing its 4th skin and was transferred to green (C¹), together with another dark brown larva which had just entered the 5th stage. The remainder were as last described, and all were advancing in the 4th stage.

June 14th. Two were on the twigs; both in the 5th stage, one dark greyish-brown and the other dark chocolate-brown. Two were on the leaves, both in the 5th stage and greyish-brown, lighter than the former two.

June 20th. Two large in the 6th stage and very dark.

June 26th. Four in the 6th stage and all very dark indeed.

July 2nd. Two of the dark larvæ had become mature and were removed. The remaining larvæ were very black and nearly mature.

July 12th. The 2 last larvæ had forced their way through the hole in the plate and were drowned. Their appearance had not changed, and it is probable that they had become mature and began to wander.

CONCLUSIONS.

In the final result we probably see the full and characteristic effect of the black twigs unmodified by the green environment in which the two youngest stages were passed.

B². *A. betularia*.

May 25th. Fifteen *betularia* larvæ transferred from green to black; all changing the 3rd skin and 14.0 mm. long. Some were becoming greenish, but most were brown.

May 29th. All examined: the colour varied very greatly, but none were altogether green although there was much green ground-colour on some. All were in the 4th stage; 1 only on the black twigs and that happened to be a particularly green one. Many light brown and many dark brown.

June 2nd. Five on twigs, 3 in the 5th stage, 1 changing 4th skin, and 1 nearly at end of 4th stage. The latter and 1 in the 5th stage dark greenish-brown, the remaining 3 very dark brown. On the leaves and green stems there were in the 5th stage, 1 green, 3 light brownish-green, and 2 light brown (1 slightly greenish); in the 4th stage, 2 brownish-green and 2 medium brown.

June 5th. On the black twigs there were 8 larvæ, 7 in the 5th stage (3 of them changing the 5th skin), 5 dark brown, 1 bright green (changing skin), and 1 brownish-green (half-grown in stage); 1 in 4th stage and brownish-green. On the light brown stem of *P. nigra* was a single larva which harmonized with it very exactly. On the leaves were 5 larvæ, 2 small in the 5th stage and light brown, 3 in the 4th, 1 dark (changing the 4th skin), 1 brownish-green, and 1 greenish-brown.

June 14th. Six larvæ in the 6th stage were on the twigs and very deep black, some of them with a small amount of greyish markings. One similar larva on green: 1 larva in the 6th stage on green was of a uniform dull light grey tint: of 2 larvæ in the 5th stage, 1 was changing the 5th skin and light brown overspread

with grey, 1 smaller and darker with less grey. Two smaller larvæ, probably in the 4th stage, or perhaps at the beginning of the 5th, were respectively lightish and darkish-brown.

June 15th. One of the darkest larvæ had become mature and was removed.

June 18th. One of the darkest larvæ become mature and was removed.

June 20th. Two very dark larvæ mature and removed. One very small one dead. Of the 6 in the last stage, 4 were very black, in 3 cases overspread with dull greyish patches; 1 was greyish on the dorsal surface, lighter grey elsewhere; the 6th and smallest somewhat resembled that last described.

June 26th. All had become mature except that last-mentioned, which had become a dark brownish-black.

July 2nd. No further change.

July 12th. The larva had become mature and was removed.

CONCLUSIONS.

The power of the black surroundings is evident, the influence of the green being only seen in the occasional grey-ness on the black larvæ, and especially in the one larva which was entirely grey. The brownish shade of the larva which was the last to reach maturity is unusual on the twigs of Turkish oak. These probable effects of the green on the larvæ which had been longest exposed to the influence of black (being the last to pupate), are contrary to the results observed in the other experiments.

B³. *A. betularia*.

June 3rd. Five *betularia* larvæ in green surroundings up to the end of the 4th stage were transferred to black. They were changing the 4th skin and 20.5 mm. long.

June 5th. One larva, a green one, was on a black twig, the others on the leaves. Four were brownish-green and 1 medium brown. All were advancing in the 5th stage and about the same size.

June 20th. Three large in the 6th stage, 1 dark smoky-black; 1 greyish smoky-black, and 1 intermediate, greenish-brown. One small one dead, 1 missing.

June 26th. One had pupated, and 1 was mature and removed. The 3rd larva was greyish smoky-black.

July 2nd. The last larva had become mature and was removed.

CONCLUSIONS.

The great power of a black environment is well shown, in the production of 2 dark larvæ and 1 intermediate. At the same time the dark larvæ were not quite the characteristic forms produced by black-barked twigs.

C. A. betularia.

May 25th. Ten of the 20 *betularia* larvæ transferred from green to black for the 3rd stage, and re-transferred to green at the end of it when they were changing the 3rd skin and 14.0 mm. long.

May 29th. All in 4th stage and all dark.

June 2nd. Four in 5th stage, 5 changing 4th skin, 1 not quite mature in 4th stage. All dark brown.

June 5th. Four changing 5th skin and 33.0 mm. long; 2 nearly mature in 5th stage; all lightish brown overspread with a greyish cloud. Three small in the 5th stage, 2 of them as above and 1 dark brown. One in 4th stage and very black.

June 14th. Six nearly mature in the 6th stage and all very dark smoky-black with a pair of distinct grey patches on the dorsal surface of each segment. Three in the 5th stage, 2 as above and 1 lighter and really intermediate.

June 15th. Three dark larvæ had become mature and were removed.

June 18th. One dark larva mature and removed.

June 20th. Two larvæ large in the 6th stage, very dark smoky-black with the paired segmental light grey patches distinct.

June 26th. The 2 larvæ above described had become mature and were removed. Of the 3 remaining larvæ, 2 were large in the 6th stage, one bright green with brown dorsal line and a small brown patch on anterior part of each side of the segments, the other smaller and darker with more brown upon it, but still with a bright green ground-colour. The third larva in the 5th stage and chocolate-brown.

July 2nd. All 3 in 6th stage, but the smallest was now intermediate. In view of the considerable development of

brown markings the other 2 can only be considered as rather on the green side of intermediate.

July 12th. The smallest larva was still feeding and still intermediate. The other two had become mature and were removed. There was no further change.

CONCLUSIONS.

These results are deeply interesting. The 6 larvæ which first became mature were certainly influenced by the green environment of the three last stages, inasmuch as the final appearance was a dark smoky-black with a pair of distinct grey patches on each segment, instead of the well-known intense dead black which is the characteristic effect of the black-barked twigs of Turkish oak. At the same time, the remarkable susceptibility to this stimulus is seen in the pronounced darkness of these 6 larvæ after only a single stage (of 5 days' duration) had been passed among black twigs. It is interesting to note that the 3 intermediate larvæ grew more slowly after May 25th, and thus passed a relatively longer time in the green environment.

C¹. *A. betularia*.

June 3rd. Two *betularia* larvæ at the beginning of the 5th stage re-transferred to green surroundings after they had been in black for the 3rd and 4th stages.

June 5th. A third larva, changing its 4th skin, was similarly re-transferred. It was of a light brown colour. Of the 2 former, 1 was nearly at the end of the 5th stage and dark brown, the other rather smaller and darkish brown overspread with grey.

June 7th. A fourth larva changing its 4th skin and a fifth at the beginning of the 5th stage were similarly re-transferred.

June 14th. Three larvæ in 6th stage, smoky-black with prominent light grey markings especially distinct in one of them. One in 5th stage and 1 changing 5th skin, both dark chocolate-brown with a little grey.

June 20th. Four large in the 6th stage, smoky-black overspread with grey. The black ground-colour resembles that of the larvæ still in black surroundings.

June 23rd. Two had become mature and were removed.

June 26th. Two mature and removed. The 5th was

now large in the 6th stage, a dark brownish-black rather than the dead black of the other 4 and those still on the black twigs.

July 12th. Mature and removed. No further change in appearance.

CONCLUSIONS.

In this case the grey which overspread the black ground-colour of 4 larvæ must be regarded as an effect of the green environment during the 2 last stages. The 5th larva took longer to develop, and there was a slight departure from the characteristic dead black of the other four.

EXPLANATION OF PLATE XVI.

Results of Experiments in 1893 upon the colour-relation between the larvæ of *Odontopera bidentata* and their environment.

All the figures are of the natural size.

FIG. 1. Nearly mature larva of *O. bidentata* showing the effect of an environment of black-barked twigs (*Quercus cerris*). This typical example of the results of Experiment I was painted by Mr. P. J. Bayzand on July 31st, 1893. All the larvæ figured on this plate were fed upon the leaves of *Populus nigra*, but they nearly always rested by day on the twigs or pieces of bark made use of in the experiments here illustrated. The larva represented in this figure is not in its normal diurnal resting position, having been disturbed; and the same is more or less the case with Figs. 3, 5, 7 and 9.

2. Nearly mature larva showing the effect of an environment of weathered pale grey barkless twigs. This typical example of the final results of Experiment VII was painted on July 28th. A little earlier the larvæ had been rather paler and resembled more closely the majority of the twigs made use of.
3. Nearly mature larva showing the effect of an environment of dark purplish-brown, glossy twigs, probably of birch. This typical result of Experiment III was painted on July 30th.
4. Nearly mature larva showing the effect of an environment of white-spotted, purplish-brown twigs of birch. This typical result of Experiment IV was painted on July 30th. Although the details of the environment were not reproduced, the larva was distinctly less dark than that shown in Fig. 3.
5. Nearly mature larva showing the effect of an environment of green leaves and shoots. The food-plant (*Populus nigra*) was employed for this purpose, all dark-barked twigs being carefully excluded. A comparison of this figure with the others on the same plate indicates that the leaves of the food-plant produce no effect when they are combined with dark twigs or lichen-covered bark; while a reference to Experiments I to XV shows that the great majority of the larvæ rest by day upon these latter objects in preference to the leaves. This typical result of Experiment VIII was painted on July 31st.

- FIG. 6. About half-grown larva showing the effect of an environment of bark covered with bluish-green lichen, probably *Physcia pulverulenta*. This typical result of Experiment XIII was painted on August 1st.
7. About half-grown larva showing the effect of the environment last described. This second typical example of the results of Experiment XIII was painted on August 3rd.
 8. Nearly mature larva showing the effect of an environment of bark covered with orange lichen, perhaps *Physcia parietina*, probably combined with *P. pulverulenta*. This typical result of Experiment XIV was painted on August 4th.
 9. Nearly mature larva showing the effect of the environment last described. This second typical example of the results of Experiment XIV was painted on August 5th.
 10. Nearly mature larva showing the effect of an environment of lichen-covered sticks. The lichen was probably *Ramalina farinacea*. This typical result of Experiment XV was painted on August 10th.
 11. Nearly mature larva showing the effect of the environment described in Fig. 6. This third typical example of the results of Experiment XIII was painted on August 31st.

Comparing the last six figures of larvæ together with the representation of the various forms of lichen-covered bark employed in the experiments, it is seen that there was no special resemblance to the characteristic features which distinguished one form of environment from the others. Thus the orange colour of the lichen did not produce any corresponding effect upon the larvæ shown in Figs. 8 and 9.

The whole results prove that *bidentata* is a larva with remarkable susceptibility to the colour of its environment. In this respect it is equal to the most sensitive of all larvæ hitherto tested—*Amphidasis betularia*. The latter is more susceptible to green leaves and shoots, becoming bright green when restricted to their influence. When exposed to lichen-covered bark, however, *bidentata* was shown, in Experiments XII to XV, to be far more sensitive.

EXPLANATION OF PLATE XVII.

Results of Experiments in 1893-4 upon the colour-relation between the larvæ of *Gastropacha quercifolia* and their environment.

All the figures are of the natural size, and all represent the normal resting position, except that the larvæ more frequently rest

with the head downwards than is shown in the plate. Perhaps the young larvæ under normal conditions invariably rest in this position.

Figs. 1—13 represent the larvæ in the autumn of 1893, just before the beginning of hybernation.

Figs. 14 and 15 represent the larvæ, nearly mature in the last stage, in May 1894.

FIG. 1. Larva of *Gastropacha quercifolia* just before hybernation, showing the effect of an environment of black-barked twigs (*Quercus cerris*). This typical example of the nine black larvæ, chequered with white, described on September 21st, 1893, was painted by Mr. Bayzand on September 25th. Although these larvæ had eaten very little, and had not grown appreciably by October 3rd, the white marks on six out of nine of them had become reduced almost to the condition represented in Fig. 3. The white patches on the larva shown in Fig. 1 had also become much duller and less conspicuous. The persistence of the process of colour-adjustment right up to the beginning of hybernation is very interesting, and contrasts remarkably with its entire cessation during and after hybernation. The difficulty with which the contour of the larvæ could be made out against the black bark is correctly rendered in Figs. 1—3.

2. Larva at the same period and exposed to the same environment as that shown in Fig. 1. The figure represents the darkest larva, without any trace of white markings, described on September 21st. The painting was made on September 23rd.
3. Larva at the same period and exposed to the same environment as that shown in Fig. 1. This typical example of five out of the six darkest larvæ, described on September 21st, was painted on September 26th.
4. Larva just before hybernation, showing the effect of an environment of lichen-covered sticks. The lichen was probably *Ramalina farinacea*. The figure represents one of the four lightest coloured larvæ produced in this environment and separated for painting on September 21st. The larva was painted on October 3rd. By October 16th, when the larvæ of series II were arranged for hybernation, many changes had taken place, but this larva remained among the lightest throughout.
5. Larva at the same period and exposed to the same environment as that shown in Fig. 4. The figure represents

one of the four lightest larvæ on October 6th when it was painted. It was not among the four lightest larvæ on September 21st, but changes took place after this date.

- FIG. 6 Larva at the same period and exposed to the same environment as that shown in Fig. 4. The figure represents one of the four lightest larvæ separated for painting on September 21st, and the only one which remained of a greyish tint, the others becoming brownish. It was painted on October 2nd.
7. Larva at the same period and exposed to the same environment as that shown in Fig. 4. The figure represents one of the commonest types of appearance on September 21st, viz. the group of six dark white-marked larvæ. The drawing was made on October 10th.
 8. Larva at the same period and exposed to the same environment as that shown in Fig. 4. Among the eight darkest larvæ of this series II on September 21st, was one in which the white markings possessed a bluish tinge. This was set aside for painting. But changes took place later on, and one of the other seven larvæ was found more nearly to represent the previous appearance of the separated larva. The former, which had become greyish, was therefore painted on October 9th.
 9. Larva at the same period and exposed to the same environment as that shown in Fig. 4. The description of Fig. 4 applies in every respect except that the larva here represented was painted on October 7th.
 10. Larva just before hibernation, showing the effect of an environment of reddish-brown stems of bramble. The larva represented was one of the two mentioned on October 16th, in which the light patches were well developed and of a brownish tint. It was painted on October 13th.
 11. Larva at the same period and exposed to the same environment as that shown in Fig. 10. The larva represented was the lightest of the seven very uniform dark brown larvæ with lighter brown patches and small white marks mentioned on October 16th. These light patches, which are not very distinct in this figure and in Fig. 13, were generally present on the 2nd, 5th, and 8th abdominal segments. The larva was painted on September 30th.
 12. Larva at the same period and exposed to the same environment as that shown in Fig. 10. The larva represented was the brown individual with the dorsal surface

overspread with grey mentioned on October 16th. The greyish appearance does not come out in the figure, the effect being merely to render the brown of a paler tint. The larva was painted on October 17th.

- FIG. 13. Larva at the same period and exposed to the same environments as that shown in Fig. 10. The description of Fig. 11 applies in every respect, except that the larva here represented was a specially dark example, and was painted on October 16th.
14. Larva, nearly mature in the last stage, showing the effect of an environment of black-barked twigs up to the beginning of hybernation. During and after hybernation the larva was placed (I, B) in an environment of lichen-covered sticks, but, as the figure indicates, it had ceased to be susceptible to such influences, and no effect was produced. Before hybernation it had been one of the five darkest larvæ. The painting was made on May 19th.
15. Larva at the same period and exposed to the same environments (I, B) both before and after hybernation as that shown in Fig. 14. Although conspicuous white patches appeared on this and other larvæ subsequent to hybernation, it is improbable that this effect was due to the lichen which formed the surroundings after the beginning of hybernation. The comparison of the whole of the larvæ indicates that they had then ceased to be susceptible to the colours of the environment. The larva was painted on May 22nd.

EXPLANATION OF PLATE XVIII.

Results of Experiments in 1893-4 upon the colour-relation between the larvæ of *Gastropacha quercifolia* and their environment.

All the figures are of the natural size, and all represent the natural resting position.

All the figures represent the larvæ in the last stage, and all but one nearly mature, in May 1894.

- FIG. 1. Larva of *Gastropacha quercifolia*, nearly mature in the last stage, showing the effect of an environment of lichen-covered sticks up to the beginning of hybernation. The lichen employed was probably *Ramalina farinacea*. During and after hybernation the larva was placed in an environment of black-barked twigs (II. G) which, it is

obvious, produced no effect whatever. The appearance of this same larva just before hibernation is represented in Plate XVII, fig. 4 or 9. The painting of the nearly mature larva was made on May 14th.

- FIG. 2. Larva, small but probably in the last stage, exposed to the same environments (II, G) both before and after hibernation, as that represented in fig. 1. Here too it is clear that the black-barked twigs which surrounded the larva during winter and spring produced absolutely no effect. The appearance of the same larva just before hibernation is represented on Plate XVII, Fig. 6. The painting of the more mature larva was made on May 28th.
3. Larva, nearly mature in the last stage, showing the effect of lichen-covered sticks throughout (II, F). The lichen was probably *Ramalina farinacea*. The appearance of this same larva just before hibernation is represented in Plate XVII, fig. 4 or 9. The painting of the nearly mature larva was made on May 25th.
 4. Larva at the same period and exposed to the same environments both before and after hibernation as that represented in Fig. 1. The larva here represented (from II, E) was the darkest of all the mature larvæ which had been exposed to an environment of lichen before hibernation (series II). There is no reason to suppose that the black twigs produced any effect in winter and spring. The larva was one of the seven darkest in series II before hibernation. The painting was made on May 17th.
 5. Larva, nearly mature in the last stage, showing the effect of reddish-brown stems of bramble throughout (III, K). The specimen represented was one of the four more spotted or lightest larvæ before hibernation, and the same relationship towards the other divisions of this series (III) was maintained during and after hibernation. The painting was finished on May 11th.
 6. Larva, nearly mature in the last stage, showing the effect reddish-brown stems of bramble before hibernation. During and after hibernation the larva was placed in an environment of black-barked twigs (III, J). It had been one of the uniform brown larvæ before the winter, and there is no reason for the belief that the black twigs introduced later produced any effect. The painting was finished on May 11th.



P. J. Bayzand, del.

André & Sleigh, Limited

Results of Experiments in 1893 upon the Colour-relation between the larvæ of *Odontopera bidentata* and their environment.



P. J. Bayzand, del.

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Effects of lichen, of black twigs, and of reddish brown sticks upon the larvæ of *Gastropacha quercifolia* (1893-4).



P. J. Bayzand, del.

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Effects of lichen and of reddish brown sticks upon the larvæ of
Gastropacha quercifolia (1893-4).